

Research Article

Testing a recently proposed framework for assessing the success of conservation translocations: the European mudminnow (*Umbra krameri*) programme in Hungary

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Abstract

Advancing conservation translocation science requires the synthesis and comparative analysis of individual case studies to generate broader evidence-based insights. However, no widely adopted framework currently standardises outcome assessment across diverse translocation programmes. Birot et al. (2025) recently proposed a candidate framework that could potentially provide such a standard. Here, we tested its applicability using the European mudminnow (*Umbra krameri*) translocation programme in Hungary. We assessed the long-term demographic success of two translocations into artificial ponds using the multi-criteria framework proposed by Birot et al. (2025). Population dynamics were monitored for 7–10 years following release, including repeated surveys of abundance, size-class structure, and recruitment. Both populations persisted beyond the species' maximum lifespan and reproduced repeatedly, as evidenced by repeated occurrences of larvae and juveniles. Detecting multiple size classes indicated recruitment across several generations. Estimated 2022 abundance relative to cumulative release numbers differed between the two populations. Despite interannual fluctuations in captures and temporary removals associated with management interventions, both populations persisted and reproduced over multiple generations. Population dynamics were classified as Establishing/Growing in Illés Pond IV + Pócos Pond B and Growing in Illés Pond VI. Overall progress scores were 0.56 and 0.70, respectively, with Establishing and Growing representing the dominant category contributions. Our results demonstrate that small, isolated, groundwater-fed artificial ponds can support persistent, self-recruiting European mudminnow populations over multiple generations despite the species' relatively low fecundity. We have established suitable habitats to provide safety and refuge for this endangered species. The framework proposed by Birot et al. (2025) was suitable for evaluating our programme. However, smaller programmes with more

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limited resources may find such a comprehensive assessment more challenging to implement. Further testing across a wider range of programmes and ecological contexts would help assess its broader applicability.

Key words: Constructed refuge ponds, demographic evaluation, marshland fish, multi-cohort structure, population persistence, post-release monitoring, self-sustaining populations

Introduction

Conservation translocation is the intentional movement and release of living organisms with the primary objective of conservation benefit. This usually involves improving the conservation status of the focal species locally or globally and/or restoring natural ecosystem functions or processes (IUCN/SSC 2013). Many animal and plant conservation translocation programmes have been conducted and continue to be undertaken worldwide (Soorae and Seddon 1998; Godefroid et al. 2024, 2025). Currently, it is impossible to provide an overall count of past and present programmes; preliminary estimates suggest that the number of projects involving plant and animal species worldwide is in the thousands, whereas programmes involving other taxa, such as fungi, appear to be rare (Bajomi 2023; Godefroid et al. 2025; Transloc 2026, Bajomi and Bendig unpublished data). Given the large and diverse number of conservation translocation programmes, assessing their outcomes and comparing their success is an important challenge for conservation science. This issue remains important, as further review studies and syntheses are needed to advance translocation science and reveal emerging patterns. We agree with Birot et al. (2025) that this requires a standardised method for measuring the success of the numerous programmes.

The book series edited by Soorae et al. 2008, Soorae (2010, 2011, 2013, 2016, 2018, 2021, 2025) and reviewed by Harding et al. (2025) has compiled numerous case studies using a broadly standardised format. The 2021 edition (Soorae 2021) contains 69 case studies. Programme managers were invited to assess their own programmes, with 24% classified as highly successful, 50% as successful, and 22% as partially successful. Only 4% were categorised as failures. Rather than applying a common set of objective criteria to assess success, each case study was evaluated against the objectives established for the individual programme. This approach appropriately accounted for each programme's specific context and intended outcomes, while also allowing greater scope for individual professional judgement in assessing programme outcomes.

Several review studies have attempted to independently quantify programme success from the available evidence. Fischer and Lindenmayer (2000), for example, provided a valuable and comprehensive review of the international reintroduction literature, covering 180 studies from 124 journal articles. They found that 26% of programmes were successful, 47% had unknown outcomes, and 27% were classified as failures. However, their findings should be treated with caution because of the inherent limitations of the available literature. Since their assessment was based on published studies, it necessarily reflects the biases present in the literature, including the likely overrepresentation of successful programmes. The available literature may therefore be affected by publication bias favouring successful

programmes (Miller et al. 2014). Of the 27 Hungarian animal reintroduction projects that reached the implementation stage, only 33% (9 programmes) resulted in an English-language publication, and most of these publications describe programmes considered successful (Bajomi 2022, 2023; Bajomi et al. 2023). This pattern suggests that the published literature may disproportionately represent successful reintroduction programmes and that a substantial proportion of programmes may remain undocumented in the international literature.

To improve the design and implementation of current and future programmes and to learn from existing experience, the methods, outcomes, and success of conservation translocations should be systematically documented, analysed, and reported. Advancing the science of conservation translocations also requires comparative analyses across sites and species (Bajomi et al. 2010; Armstrong and Seddon 2011; Birot et al. 2025). Reviews and other synthesis studies seeking to draw general conclusions across multiple taxa must therefore bring together evidence from numerous programmes conducted under different conditions and using different approaches. However, at least 12 definitions of reintroduction success have been identified in the literature (Bajomi 2007), and programme managers have developed a range of approaches for assessing programme outcomes. As a result, success is currently assessed using a wide range of definitions and criteria, making meaningful comparisons among programmes difficult. A widely applicable, standardised, and objective framework for evaluating translocation success would therefore be highly valuable for facilitating meaningful comparisons and evidence synthesis across programmes. We strongly agree with Birot et al. (2025) that a standardised measure of success is needed across the many translocation case studies that will be published in the international literature. In this context, platform initiatives such as the Godefroid et al. (2024 and 2025) and Transloc (2026) databases constitute significant milestones in conservation translocation science, providing the infrastructure needed to systematically aggregate a large number of individual programmes.

Conservation translocation events can be viewed as ecological experiments, aligning with the conceptual framework proposed by Sarrazin and Barbault (1996) to integrate management practices with robust ecological theory. When large numbers of such experiments are conducted across different species, sites, and environmental conditions, with both shared and contrasting characteristics, standardised measures of success enable comparison and synthesis of their results. Such large-scale evidence could generate valuable insights into ecological processes and contribute to the development of basic ecological theory.

A new operational tool proposed by Birot et al. (2025) is a potential candidate for international standardisation because it uses objective measures, can be applied with varying levels of available information, and suits different taxa and types of conservation translocations. According to the authors, “this multi-criteria approach will allow the broad-scale assessment of the demographic success of translocation programmes consistently, while accounting for the availability of monitoring information. Regularly assessing translocation success will also inform about the need for potential interventions” (Birot et al. 2025). The operational tool was designed for translocated populations, but it could eventually be applied to any other populations exhibiting comparable dynamics, such as biological invasions. Birot et al. (2025) tested the method

on two case studies involving “contrasting taxonomic groups and life cycles: a large vertebrate (*Gyps fulvus*) and an herbaceous plant (*Arenaria grandiflora*)”.

Translocation is an increasingly used conservation tool for freshwater fishes worldwide, but the demographic outcomes of artificial refuge habitats are rarely evaluated using standardised demographic frameworks (Bubac et al. 2019; Pearce et al. 2026). In this paper, we provide an independent evaluation of the framework proposed by Birot et al. (2025) by applying it to conservation translocations of European mudminnow (*Umbra krameri* Walbaum, 1792; Figs 1, 5) carried out as part of the European Mudminnow Conservation Pilot Programme in Hungary. To our knowledge, this is the first independent application of the framework and the first study to further explore its applicability through an additional conservation translocation case study.

Tavirózsa Association launched this comprehensive project aiming to preserve and strengthen mudminnow populations in Hungary (Tatár et al. 2010; Müller et al. 2011; Bajomi et al. 2013; Demény et al. 2014; Kucska et al. 2016; Tatár et al. 2017; Müller et al. 2020; Wanzenböck et al. 2026). The vulnerable fish, European mudminnow, lives in shallow waters rich in aquatic plants and rarely grows larger than 10 cm (Ford 2024). According to the literature, egg production is low and highly variable (ranging from 75 to 2528 eggs), but females care for the eggs (Heckel 1847; Makarov 1936; Balon 1967; Kováč 1995; Wilhelm 1996; Makara and Stráňai 1980; Müller et al. 2011).



Figure 1. 38-day-old *Umbra krameri* fry reared at the Hungarian University of Agriculture and Life Sciences for stocking. This fish is one of the founders of the population in Illés Pond IV + Pócos Pond B (Szada origin). Photo by Csaba Posztós.

During our conservation programme, we introduced European mudminnow into six artificially created refuge habitats (Illés Pond I, III, IV, VI, VII, VIII) situated close to one another in the Szada Pilot Area between 2010 and 2024 (Tatár et al. 2026). The stocked fish were produced through ex situ laboratory breeding and in situ cage breeding of rescued individuals (Tóth et al. 2026). The aim was to establish suitable habitats for the refuge populations of European mudminnows (de Oliveira et al. 2022).

Materials and methods

Study area

Our research focused on Illés Pond VI and Illés Pond IV + Pócos Pond B in the Szada Pilot Area (Tatár et al. 2026). We discovered Pócos Pond B in 2009; Illés Pond IV, an artificial pond, was connected to it in 2010 to expand the habitat. These groundwater-fed artificial water bodies each have aquatic vegetation, a water surface area of 40 m², and an average depth of 1.5 meters. None of the ponds is connected to any watercourses, which prevents the different mudminnow populations from mixing and reduces the chances of invasive Amur sleeper (*Perccottus glenii*) establishing and spreading.

Stock data

The last introductions of mudminnow into Illés Pond IV + Pócos Pond B and Illés Pond VI in the Szada Pilot Area took place in 2012 and 2015, respectively. By 2022, the mudminnow populations in these sites had persisted for 10 and 7 years, respectively, without further releases (Table 1). Mudminnow can reach sexual maturity at one year old, and the maximum expected lifespan is 6–7 years (Wilhelm 2007). We can therefore be sure that in these ponds, all fish caught after 7 years were born locally and are the offspring of the released individuals. Seven ponds in the Szada Pilot Area are suitable for mudminnow, but only two have not been stocked for more than seven years. It should be noted here that we have also stocked Illés Pond IV + Pócos Pond B and Illés Pond VI with other marshland fish: crucian carp (*Carassius carassius*) and weatherfish (*Misgurnus fossilis*).

Fish fauna monitoring

Fish assemblages were sampled using an electric fishing device (Hans Grassl IG200/2b, PDC, 80–90 Hz, 350–650 V, max. 1,5 kW, Hans Grassl GmbH, Schöna am Königssee, Germany), with samples covering two-thirds of the pond shore. Some sections of the pond shoreline were difficult to access, but most were accessible and suitable for an adequate survey of the fish population. Captured fish were identified, measured, counted, and released immediately. Adults temporarily removed during spring surveys for controlled breeding, as well as those captured in October 2018 in Illés Pond IV + Pócos Pond B, were returned to their ponds approximately two months later and were therefore not treated as permanent removals in interannual population-growth calculations. We sampled all fish species, but this article focuses only on the European mudminnow.

Table 1. European mudminnow stocking and catching data of the Szada Pilot Area (Hungary).

Places of origin of the propagated fish	Pócos Pond B (Pest Plain, Szada)	Czuczor-sziget (Ráckeve Danube Branch, Dunaharaszti)
Geographical coordinates and elevation above sea level [†]	47.6251°N, 19.2965°E approx. 190 m	47.37225°N, 19.08917°E approx. 110 m
Refuge habitats (Szada Pilot Area)	Illés Pond IV + Pócos Pond B	Illés Pond VI
Geographical coordinates and elevation above sea level	47.6249°N, 19.2963°E approx. 190 m	47.625144°N, 19.296486°E approx. 190 m
Release years	2010–2012	2011–2015
Number of stocked mudminnows at last stocking (date)	371 (29. 05. 2012)	89 (01. 09. 2015; 08. 09. 2015)
Total number of released individuals (N _r)	420	109
Period without fish stocking	2013–2022 [§]	2016–2022 [§]
Catch in the last full pre-release survey - ind. (date)	17 (18. 03. 2022)	70 (02. 07. 2022)

[†] Measured with a GPS device (Garmin eTrex Legend HCX) with 15-meter accuracy

[§] In 2022, mudminnows were introduced, but only after fish fauna monitoring.



Figure 2. Fish fauna monitoring in Illés Pond VI in the Szada Pilot Area. Photo by Sándor Tatár.

Monitoring was conducted 1–2 times per year between 2013 and 2022 (Fig. 2). Note that the effectiveness of electric fishing was not significantly affected by submerged macrophyte cover, which remained low during spring monitoring (max. 10%). Because capture probability was not estimated directly in the study ponds, a 50% capture efficiency was assumed. Previous European studies indicate that single-pass electrofishing capture probability may vary approximately between 31% and 65% among species and habitats in larger waterbodies (Benejam et al. 2012; Sály et al. 2021), while studies in small shallow lakes demonstrate additional method-, species- and habitat-specific biases (Perrow

et al. 1996; Jurajda et al. 2009; Kajgrova et al. 2023). In spring 2016, 2021, and 2022, we conducted partial surveys (covering 50% of the ponds) to avoid disturbing fish during spawning.

Size-class structure analysis of fish

To assess the size-class structure of the translocated populations, we measured the standard length (SL) of a subsample of captured European mudminnow individuals in most survey years (8/9 years of Illés Pond IV + Pócos Pond B, and 4/7 years of Illés Pond VI monitoring). We divided the caught fish into five size classes: 0–20, 21–40, 41–60, 61–80, and ≥ 81 mm.

Associations between mean catch per survey and mean standard length were evaluated using Spearman's rank correlation coefficient (Zar 2010).

Evaluation of translocation success

We assessed the success of the two translocated mudminnow populations in Illés Pond IV + Pócos Pond B and Illés Pond VI using the framework developed by Birot et al. (2025). This operational framework provides a standardised approach for assessing progress in conservation translocation programmes, using a category-based system structured like the IUCN Red List. It distinguishes eight progress categories: Regulating, Growing, Weakening, Failing, Failed, Data Deficient, Not Evaluated, Establishing (after establishment, the category Establishing is replaced by Weakening when the population shows a less favourable demographic state). Because neither population had previously been formally assessed as established using this framework, we applied the pre-establishment evaluation grid. The framework is designed to apply across taxa and accommodate variation in the amount and quality of demographic information available from monitoring programmes. It evaluates four key dimensions of translocated population development: survival and persistence (A), recruitment (B), spatial distribution (C), and population dynamics (D). Each criterion is divided into three sub-criteria representing progressively higher levels of evidential robustness. Depending on the available information, these sub-criteria enable assessment of translocation success using increasingly detailed demographic evidence. For each sub-criterion, the available evidence is evaluated using relevant demographic information, including evidence of persistence, reproduction or recruitment, population distribution, and changes in population size or structure, as appropriate. The observed evidence is then compared with the threshold values defined by Birot et al. (2025, Table 1) to assign the corresponding population-status category. Threshold values are presented in detail in Table 2 of Birot et al. (2025). Where the available information is insufficient to distinguish reliably between categories, the criterion is classified as Data Deficient rather than inferring population status from limited evidence. The framework therefore allows assessments based on relatively basic demographic information while also accommodating more detailed monitoring data.

Each of the four criteria comprises three sub-criteria with increasing “Robustness of Evaluation (RoE)”, reflecting differences in the amount and quality of available information and the level of confidence with which the corresponding assessment can be made. RoE values of 10%, 50% and 100% are assigned to the three sub-criteria, respectively. For each criterion, the sub-criterion with the

Table 2. Mean standard length (SL) data of the caught European mudminnows in the ponds of the Szada Pilot Area. We observed a moderate negative association between mean catch per survey and mean body size (Spearman's rank correlation: $\rho = -0.64$, $p = 0.09$, $n = 8$; Table 2).

	Year	No. of individuals /survey	Mean SL (mm)
Illés Pond IV + Pócos Pond B	2014	35	54.6
	2015	47	63.6
	2017	14	63.0
	2018	6	75.4
	2019	10	65.0
Illés Pond VI	2017	17	45.5
	2019	18	51.4
	2022	70	35.0

highest RoE, as supported by the available evidence, is used in the final evaluation. Where no adequate information is available to evaluate a criterion, it is classified as Data Deficient. Birot et al. (2025) also assessed the framework's sensitivity to alternative RoE weighting schemes and found that changing these weights had little effect on the resulting evaluations. At the end of the evaluation process, an overall progress score (S) is calculated, ranging from 0 to 1. It provides an integrated measure of programme progress at the time of evaluation.

We evaluated each population at its last full survey in 2022, conducted before any subsequent releases or transfers. For criterion A2, the observed catch (Ct) was converted to an abundance estimate (Nt) using an assumed capture probability of 0.50 ($Nt = Ct/0.50$). Because capture probability was not estimated directly, the values were treated as scenario-based estimates rather than detection-corrected population estimates. For D2, the reconstructed annual growth rate was calculated as $\lambda_e = (Nt/Na)^{1/(t-a)}$ using consecutive full censuses; partial surveys were excluded. Because the same assumed capture probability (0.50) was applied to both abundance estimates, this correction cancels out in the abundance ratio. For Illés Pond IV + Pócos Pond B, D3a and D3b were additionally calculated from the first full spring census available for each year using the five annual growth rates preceding the 2022 assessment. We calculated the overall progress score (S) following Birot et al. (2025) as the RoE-weighted mean of the four criterion scores: Failed = 0, Failing = 0.25, Establishing = 0.50, Growing = 0.75 and Regulating = 1.00. When a criterion supported two categories, the scores for those categories were averaged before RoE weighting. Relative category contributions (Px) were calculated by assigning each criterion a total contribution of 100%, divided equally among the categories supported by that criterion, and averaging these contributions across criteria A–D.

Results

Stock size trend and size-class structure of the established populations

Illés Pond IV + Pócos Pond B and Illés Pond VI retained individuals for subsequent years after the final release, with repeated detections of larvae and multiple size classes (Figs 3, 4). No dispersal beyond the isolated ponds was detected, but we observed juveniles and adults over the long term (Figs 5–7).

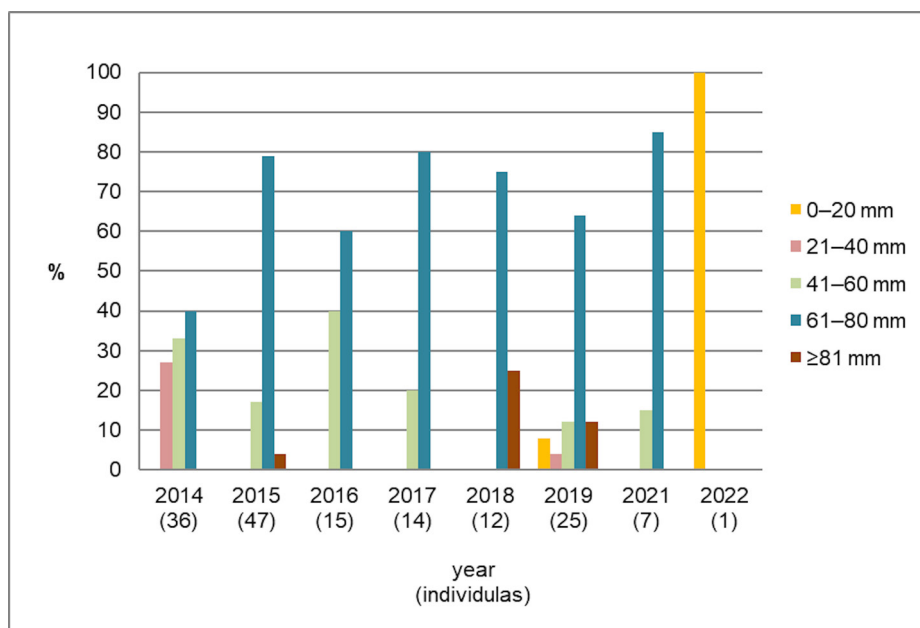


Figure 3. Annual size-class distribution of European mudminnow in Illés Pond IV + Pócos Pond B of Szada Pilot Area. Partial surveys were conducted in 2016, 2021, and 2022. A severe drought caused a significant drop in water levels and deterioration of the pond in 2021–2022.

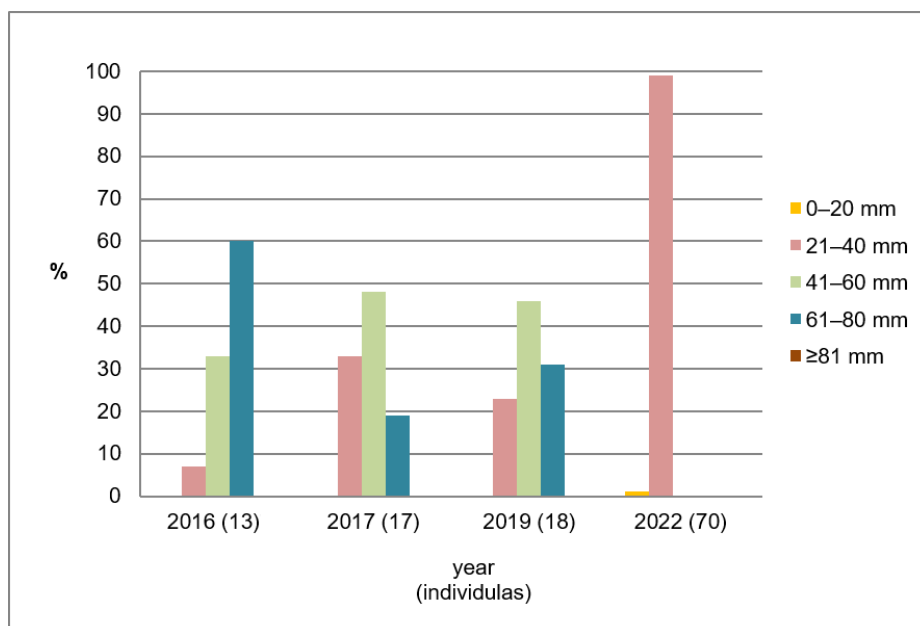


Figure 4. Annual size-class distribution of European mudminnow in Illés Pond VI. Partial surveys were conducted in 2016 and 2022. A severe drought caused a significant drop in water levels and deterioration of the pond in 2021–2022.

Evaluation of translocation success

Due to deficient data, the analysis of translocation success was limited, but we nevertheless obtained a comprehensive picture of the development of European mudminnow populations. At the same time, the combined evidence from



Figure 5. Three generations of European mudminnows in the fishing net. Photo by Sándor Tatár.

long-term persistence, recurrent recruitment, and stable size-class structure allowed a coherent assessment across multiple criteria (see Table 3).

The apparent-survival criteria (A1 and A2) yielded contrasting outcomes. Individuals were detected for 10 years after the last release in Illés Pond IV + Pócos Pond B and for 7 years in Illés Pond VI, with repeated captures in both populations. Under the 50% capture-probability scenario, the 2022 abundance estimate for Illés Pond IV + Pócos Pond B was $N_t = 34$ relative to $N_r = 420$, corresponding to the Failing category under A2. In contrast, the estimated abundance for Illés Pond VI was $N_t = 140$ relative to $N_r = 109$, corresponding to the Growing/Regulating category. These scenario-based estimates should not be interpreted as direct estimates of the survival of released individuals because the populations also contained locally born descendants. The evaluations indicated the “Growing/Regulating” category in recruitment sub-criteria (B1, B2). Larvae and 1+ individuals were recorded in multiple years, indicating repeated spawning in both ponds. Furthermore, the presence of various size classes and recurrent recruitment suggests unequivocal reproduction by F1+ individuals in Illés Pond IV + Pócos Pond B and Illés Pond VI.

All ponds have been categorised as “Establishing” based on spatial distribution (C2, C3) because all recorded individuals are confined to the isolated water bodies. The AOTP (Area of Occupation of the Translocated Population) remains stable (one 4 km² cell); no expansion was possible from ponds. Population dynamics could be evaluated using quantitative growth-rate criteria. In Illés Pond IV + Pócos Pond B, D2 indicated Failing ($\lambda_e = 0.55$). In contrast, the more robust five-year D3 assessment indicated Growing based on mean growth rate ($\lambda_m = 1.04$) and Establishing based on growth-rate variation ($\sigma^2\lambda = 0.742$), resulting in an Establishing/Growing D3 outcome (RoE = 100%). In Illés Pond VI, D2 indicated Growing ($\lambda_e = 4.38$; RoE = 50%), whereas D3 could not be calculated due to incomplete annual monitoring.

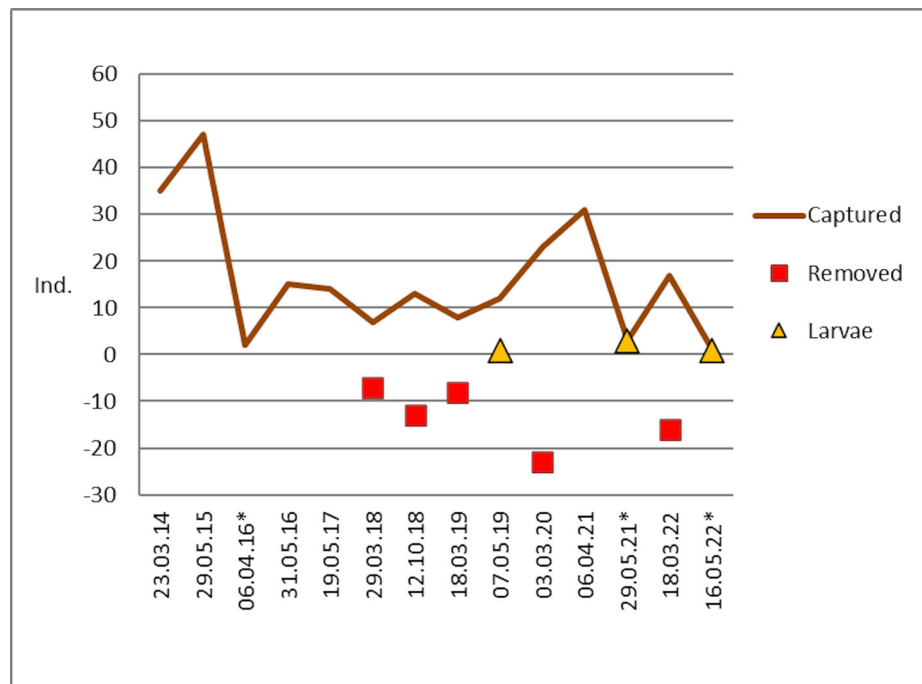


Figure 6. The number of captured and removed European mudminnow individuals from Illés Pond IV + Pócos Pond B. The negative numbers indicate removals. * Partial surveys were conducted. Notes: During several spring surveys in ponds, a portion of the captured adults was temporarily removed for controlled breeding in the laboratory. These removals reduced the number of spawning-capable individuals in the pond, but all adults were returned after propagation.

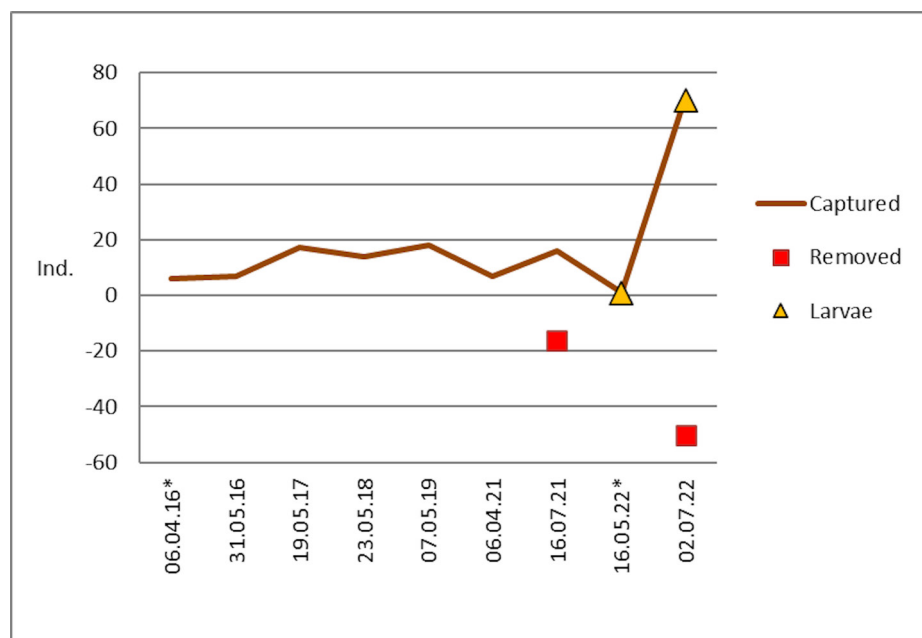


Figure 7. The number of captured and removed European mudminnow individuals at Illés Pond VI. The negative numbers indicate removals. * Partial surveys were conducted. Notes: In Illés Pond VI, severe drops in water level in July 2021 and 2022 led to emergency rescue operations; some individuals were temporarily relocated and reintroduced in October 2022, while others were transferred to the pond at MATE Botanical Garden, which has a continuous water supply.

Table 3. Detailed evaluation of the European mudminnow Conservation Programme with Birot's A-D criteria (Birot et al. 2025). Abbreviations: RoE = Robustness of Evaluation (%). Estimated 2022 abundances (Nt) were derived from the last full surveys conducted before subsequent releases or transfers. Nt was calculated under an assumed 50% capture-efficiency scenario ($N_t = C_t/0.50$).

Criteria and sub-criteria	Illés Pond IV + Pócos Pond B	Progress category	RoE (in %)	Illés Pond VI	Progress category	RoE (in %)
A - Apparent survival	Justification			Justification		
A1 – Individuals still alive in the study area	Individuals were detected over 10 years after the last release, with repeated captures.	Failing / Establishing / Growing / Regulating	10	Individuals were detected for 7 years after the previous release, with repeated captures.	Failing / Establishing / Growing / Regulating	10
A2 - Number of individuals alive in the study area (N_t) compared to the total number of released individuals (N_r)	Long-term multi-cohort persistence relative to the initial number of founders and larvae released. ($N_t = 34$; $N_r = 420$)	Failing	50	Multi-year persistence of several cohorts relative to the moderate number of founders released. ($N_t = 140$; $N_r = 109$)	Growing/Regulating	50
A3 – Mean apparent annual survival rate in the study area (SR) compared to the minimum theoretical survival rate (S_{min}) AND trend of S	Data deficient	NA	0	Data deficient	NA	0
B - Recruitment	Justification			Justification		
B1 – Reproduction or immigration	Larvae and 1+ individuals were recorded in multiple years, indicating repeated spawning.	Growing/Regulating	10	A strong larval event was recorded in 2022, and the presence of small-size classes indicates successful reproduction.	Growing/Regulating	10
B2 – Breeders' origin; Translocated individuals (F0)	Not relevant (reproduction by F1+ generations is confirmed - see below).	Not relevant		Not relevant (reproduction by F1+ generations is confirmed - see below).	Not relevant	
Wild-born individuals (F1+)	Capture times and size classes suggest reproduction by founders. Multiple age classes and recurrent recruitment also suggest reproduction by F1+ individuals.	Growing/Regulating	50	Capture times and size classes suggest reproduction by founders. Multiple age classes and recurrent recruitment also suggest reproduction by F1+ individuals.	Growing/Regulating	50
B3 – Mean breeding success (BS) compared to the minimum theoretical breeding success (BS_{min}) AND mean variation of BS (σ^2_{BS})	Data deficient	NA	0	Data deficient	NA	0
C – Spatial distribution	Justification			Justification		
C1 – Individuals still inside the translocation area	All individuals detected within the release pond; no records outside the pond.	Establishing / Growing / Regulating	10	All individuals detected within the release pond; no records outside the pond.	Establishing / Growing / Regulating	10

Criteria and sub-criteria	Illés Pond IV + Pócos Pond B	Progress category	RoE (in %)	Illés Pond VI	Progress category	RoE (in %)
C2 – Individuals inside and/or outside the translocation area	All detected individuals were within the defined translocation area, and none were recorded outside it. The pond is hydrologically isolated from other surface waters.	Establishing	50	All detected individuals were within the defined translocation area, and none were recorded outside it. The pond is hydrologically isolated from other surface waters.	Establishing	50
C3 – Evolution of spatial coverage: AOTP or EOTP	Spatial coverage remains stable over time; the population is restricted to a single pond and does not expand.	Establishing	100	Spatial coverage remains stable over time; the population is restricted to a single pond and does not expand.	Establishing	100
D – Population dynamics	Justification			Justification		
D1 – Increasing or decreasing number of individuals	Note: Catch indices showed no consistent long-term increase or decline, indicating an approximately stable pattern. Temporary removals for breeding and unfavourable changes in the pond's ecological conditions prevented the observed catches from reflecting a reliable population-size trend. However, because the population had persisted for more than three years and more than one generation after release, this pattern did not correspond to any category explicitly defined under the pre-establishment D1 criterion.	Data deficient	0	Note: Catch indices showed no consistent long-term increase or decline, indicating an approximately stable pattern. Temporary removals for breeding and unfavourable changes in the pond's ecological conditions prevented the observed catches from reflecting a reliable population-size trend. However, because the population had persisted for more than three years and more than one generation after release, this pattern did not correspond to any category explicitly defined under the pre-establishment D1 criterion.	Data deficient	0
D2 – Reconstructed annual growth rate (λ_e)	The reconstructed annual growth rate between the last two full censuses was $\lambda_e = 34/62 = 0.55$. We did not treat temporary breeding removals as permanent losses because adults returned within the same year.	Failing	50	The reconstructed annual growth rate between the 2021 and 2022 full July censuses was $\lambda_e = 140/32 = 4.38$	Growing	50
D3a – Mean annual growth rate (λ_m)	The five-year geometric mean annual growth rate was $\lambda_m = 1.04$	Growing	100	Data deficient	NA	0
D3b – Variation of the annual growth rate (σ_{λ_m})	The five-year variance of annual growth rates was $\sigma_{\lambda_m} = 0.742$, exceeding $0.05\lambda_m$	Establishing	100	Data deficient	NA	0

We observed several size classes and repeated recruitment across years, despite temporary fish removals and unfavourable ecological changes associated with severe droughts in 2021–22, in Illés Pond IV and Pócos Pond B (Tatár et al. 2026).

For Illés Pond IV + Pócos Pond B, the criterion scores were A = 0.25 (RoE = 50%), B = 0.875 (50%), C = 0.50 (100%) and D = 0.625 (100%), resulting in an overall progress score of S = 0.56 and a mean RoE of 75%. For Illés Pond VI, the corresponding scores were A = 0.875 (RoE = 50%), B = 0.875 (RoE = 50%), C = 0.50 (RoE = 100%), and D = 0.75 (RoE = 50%), resulting in S = 0.70 and a mean RoE of 62.5%. The dominant category contribution was Establishing (37.5%) in the former population and Growing (50%) in the latter.

Discussion

Size-class structure of the reintroduced populations

In both ponds, the size-class structure indicated multiple cohorts in most sampling years (Figs 3, 4). In Illés Pond IV + Pócos Pond B, we also recorded small juveniles and large adults (≥ 80 mm SL). Illés Pond VI showed a similarly broad size range. We mostly detected low larval numbers across all ponds, but their small size made them difficult to catch. The coexistence of multiple size classes within years, and the repeated occurrence of young-of-the-year and 1+ fish, demonstrate regular recruitment and survival across generations. Although temporary removals reduced the number of sexually mature fish during certain sampling events before the spawning season, they did not adversely affect long-term population trends. The observed size-class structure is entirely consistent with self-sustaining, multi-cohort populations. The presence of several size classes, including juveniles and older adults, suggests that reintroduced European mudminnow not only survived but also reproduced successfully over multiple generations in both ponds. The long-term presence of juveniles and adults indicated stable population levels in Illés Pond IV + Pócos Pond B and Illés Pond VI as well (Figs 3, 4).

The negative relationship between mean catch per survey and mean standard length was not statistically significant and likely reflects the combined effects of episodic recruitment, small sample sizes, and substantial environmental variability (e.g., driven by climate change), typical of small artificial ponds (Tatár et al. 2026). Density-dependent growth is a widespread regulatory mechanism in fish populations, in which increased population density reduces individual growth rates due to limited resources (Lorenzen and Enberg 2002; Hazlerigg et al. 2012). Such effects may be particularly pronounced or temporally unstable in small water bodies, where strong environmental fluctuations can override simple density–growth relationships (Matte et al. 2020).

Evaluation of translocation success

Several factors explain why the number of surviving fish in 2022 was lower than the number released. On the one hand, the ponds' carrying capacities were limited by their small size, and their 60 m³ volume is usually reduced by up to 40% by the end of a dry summer. In contrast, compared with larger water bodies, they are more exposed to climatic conditions that drive unfavourable ecological states (Tatár et al. 2026). The relatively low typical catches are consistent with the limited carrying capacities of Illés Pond IV + Pócos Pond B and Illés Pond VI, in the Szada Pilot Area (Table 2). For the 217 fish caught over six years and eight surveys, the median catch was 17.5 individuals (IQR = Q3–Q1 = 38–

13 = 25). Our data indicate substantial variability in catch sizes, suggesting that the median and IQR provide a more robust description of typical catches than the mean and standard deviation. To ensure that a population well adapted to the new environment could develop through natural selection, we introduced more fry (371 and 89 ind.) than the estimated carrying capacity would allow.

The A2 subcriteria outcomes differed markedly between the two populations. In Illés Pond IV + Pócos Pond B, the 2022 abundance estimate ($N_t = 34$) remained substantially below the cumulative number released ($N_r = 420$), resulting in a Failing classification. This difference may reflect releases above the pond's carrying capacity, imperfect detection, environmental fluctuations, and management-related removals. In Illés Pond VI, the strong larval cohort recorded in 2022 resulted in an estimated abundance of $N_t = 140$, exceeding both $N_r = 109$ and the 1.2 N_r threshold, thereby supporting a Growing/Regulating classification under A2. However, the N_t/N_r ratio should not be interpreted as the survival rate of founding individuals because N_t includes their locally born descendants and depends on an assumed capture probability.

The combination of multi-year survival, recurring recruitment, and a multi-size-class structure of mudminnow provides strong evidence that both reintroduced populations were self-sustaining. Despite limited quantitative demographic data, long-term persistence, repeated recruitment and multiple size classes indicate that both populations became established and reproduced over several generations. Interpreting quantitative growth-rate criteria requires caution because abundance estimates were based on an assumed capture probability, and population dynamics were influenced by management interventions and pronounced environmental fluctuations. Management-related removals (e.g. breeding; Tóth et al. 2026) and marked fluctuations in pond conditions, including extreme water levels and temperatures, may also have reduced reproductive output and population size, potentially preventing attainment of, or obscuring evidence for, a "Regulating" state in both ponds.

Notably, despite long-term persistence, recurrent reproduction, and an apparently stable population near the pond's carrying capacity, the dominant framework category for Illés Pond IV + Pócos Pond B remained Establishing. This discrepancy illustrates a potential limitation of the framework when applied to small, isolated populations, where strong interannual fluctuations may reflect normal dynamics rather than incomplete establishment.

A key advantage of the framework developed by Birot et al. (2025) is that it can be applied even when only basic demographic information is available, with the minimum information required being:

- individuals still alive in the study area,
- reproduction or immigration occurring in the area,
- individuals still inside the translocation area (e.g. not having spread outside), and
- an increasing or decreasing number of individuals.

However, programme managers collecting detailed demographic data can also use the framework in their assessments, thereby providing a standardised approach to assessing translocation success across programmes. The level of demographic information available for our programme falls between these two extremes.

Based on Seddon's (1999) simple definition, the success of our programme can be readily demonstrated by the available evidence (Seddon 1999). Nevertheless, we fully agree with Birot et al. (2025) that conservation translocation programmes need standardised assessment and reporting of success. We therefore applied their framework to our case study to test its applicability and to assess whether it could provide a more standardised and comparable assessment of translocation success. We also wished to report the results of our programme within this new framework.

The global English-language literature on animal reintroductions between 1891 and 2015 comprises approximately 9,000 written sources, including scientific publications, book chapters, theses, reports, manuscripts, and other documents (Bajomi et al. 2010; Bajomi 2023). This estimate does not include literature concerning other types of conservation translocations defined by IUCN/SSC (2013), such as reinforcements, assisted colonisations, and ecological replacements. It also does not include texts on animal reintroductions published since 2015, which likely comprise several thousand sources, assuming an annual publication rate of approximately 100–300 sources. The literature on plant translocations is likely extensive as well. Much of this literature consists of case studies describing individual programmes, and information across studies likely varies considerably in both scope and detail. In this context, we should consider “backward compatibility” when developing and applying new frameworks for assessing translocation outcomes. Within the existing literature, terms such as “successful”, “unsuccessful”, and “partly successful/not yet known” have been widely used, although their definitions and underlying criteria have varied considerably among studies. Consequently, applying a more standardised framework to this extensive body of literature may pose practical challenges.

The framework proposed by Birot et al. (2025) represents a valuable step towards more structured and comprehensive assessments; however, its application to historical programmes may be constrained by the availability and consistency of the underlying data. Even for contemporary programmes, obtaining and integrating the demographic information required for such an assessment can be demanding, while recovering comparable demographic data for older programmes from the published literature may be considerably more challenging.

The conservation translocation community should consider how to integrate knowledge generated under diverse terminology and reporting practices into future syntheses and reviews to enable more comprehensive assessments of translocation outcomes. Although demographic models appear in a relatively large number of studies published in the international peer-reviewed literature, these studies likely represent only the tip of the iceberg. A considerably larger number of reintroduction programmes may not employ demographic modelling, partly because these approaches require detailed demographic data and specialised modelling expertise. Building such models requires sufficiently detailed demographic data on target populations (Neves et al. 2026, Rose et al. 2026), which may not be routinely collected in many conservation translocation programmes. The situation in Hungary provides an illustrative example. We previously reviewed animal reintroduction programmes implemented in Hungary (Olajos 2012; Bajomi 2023; Bajomi et al. 2023) and identified 27 species for which reintroduction had been undertaken. None of these projects employed demographic modelling. This may reflect, at least in part, the substantial data

requirements and methodological complexity associated with demographic modelling, rather than a lack of interest in, or commitment to, rigorous population assessment among programme practitioners.

While some programmes have been systematically monitored, documented and reported in the scientific literature, information on many projects remains limited. In particular, even basic demographic parameters, such as estimated population size after 1, 5, and, where appropriate, 10 or 20 years, as recommended by Sutherland et al. (2010), are often unavailable. This observation may reflect a broader challenge in conservation practice, as a considerable proportion of animal, plant and other conservation programmes worldwide may not be monitored or documented to the extent necessary to support subsequent evaluation. This is particularly relevant because learning from unsuccessful or less successful interventions is essential for advancing conservation practice, yet such cases may be disproportionately underrepresented in the available literature.

We consider it unlikely that a comprehensive analysis such as that conducted by Birot et al. (2025) would be undertaken for programmes with inadequate monitoring and documentation and insufficient publication of results. Therefore, we suggest complementing the framework proposed by Birot et al. (2025) with a simple assessment option based on Seddon's (1999) approach. This would provide a pragmatic way to assess programmes for which the detailed information required by the more comprehensive assessment framework of Birot et al. (2025) or by demographic models is not available.

We suggest that, in future calls for proposals, funding organisations require conservation translocation programmes to be adequately monitored, documented, and published in accordance with a standardised framework to be developed and adopted by the professional community. Recently, other authors have also begun developing alternative frameworks for use as standards, including Van Leeuwen and Fieschi-Méric (2026), Cowen et al. (2024), and Marino et al. (2024). In the future, these frameworks could also be tested empirically with data coming from real-life programmes.

Conclusions

Our results demonstrate that small, isolated, artificial groundwater-fed ponds can maintain persistent, self-recruiting European mudminnow populations over multiple generations, despite the species' relatively low fecundity. However, the ponds in the Szada Pilot Area may require further preparation to address anticipated climate change effects (Tatár et al. 2026).

The framework proposed by Birot et al. (2025) provided a useful approach for assessing progress in our conservation translocation programme. Its operational structure offers flexibility for managers with varying demographic and modelling expertise, allowing assessment based on available information and analytical capacity.

Our application also highlighted aspects that warrant further consideration as the framework is tested across more species, programmes, and ecological contexts. In particular, stable but strongly fluctuating populations in small, isolated habitats may not always fit unambiguously into predefined progress categories, highlighting the value of further testing across diverse conservation translocation situations.

Although the framework can be applied with relatively simple data, evaluating it may require some effort and interpretation, potentially limiting uptake in smaller programmes. A potential next step could be to develop large databases that enable reviews and syntheses to include, as far as possible, all programmes. Such syntheses would require results from all programmes, including unsuccessful, less well-designed or poorly documented ones, to be available in the international literature.

If a standardised evaluation approach becomes widely adopted, accessible and easy-to-use guidelines in several of the world's most widely spoken languages would be valuable. We encourage programme leaders to publish their methods and results in English to advance translocation science. Funding organisations, governmental authorities and relevant international bodies could also help promote standardised evaluation and publication of programme methods and outcomes.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Artificial Intelligence (AI) use

The authors accept full responsibility for the content of the manuscript, including the disclosure of any use of AI.

The following AI tools were used in the preparation of this manuscript:

AI tools: DeepL, ChatGPT, and Grammarly.

Description: All ideas and findings presented in this article are the authors' own, and we did not use artificial intelligence to develop them. Three AI-based language-editing tools (DeepL, ChatGPT, and Grammarly) were used to assist with English writing and translation and to improve the manuscript's clarity and grammatical accuracy. The authors devised the main structure of the manuscript but used ChatGPT to organise the text into a few paragraphs.

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Author contributions

Sándor Tatár launched the programme in 2008 and has managed it ever since. Tamás Müller has been involved in breeding and stocking the fish. Balázs Tóth monitored the fish fauna, while Bálint Bajomi helped document and publish the results. Bálint Bajomi and Sándor Tatár contributed equally to the study's conceptualisation, research planning, literature review, and evaluation of the results. Tamás Müller and Krisztián Nyeste contributed equally to the study's conceptualisation, supervision, and coordination. Sándor Tatár and Igor Dukay participated in data processing. All authors approved the final version of the manuscript.

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Data availability

All of the data that support the findings of this study are available in the main text.