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RESEARCH ARTICLE

Effects of active protection of the endangered fish lake minnow, *Eupallasella (Rhynchocypris) percnurus* (Pallas, 1814), on its occurrence in Mazowieckie Voivodeship in Poland

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Abstract. Mazowieckie Voivodeship was the first region in Poland to widely apply fish translocations for the active protection of the lake minnow, *Eupallasella (Rhynchocypris) percnurus*, a species of the family Leuciscidae at serious risk of extinction. These efforts began in 2002 and concluded in 2018, during which time over 21,000 juvenile fish from aquaculture were translocated to 13 water bodies. As a result, five new viable populations were established with the use of 17,000 fish. Three of these were confirmed to be viable in 2024, and one other probably also still exists. The failure of all the other translocations were habitat loss from drying up or population extinction caused by introductions of predatory fish species. The three or four new lake minnow populations contribute considerably to the present status of this species in the voivodeship, because the total number of all sites in 2024 did not exceed seven. These new populations also play a notable role in Poland, as there are likely not more than 80 lake minnow sites at present.

Keywords: conservation, fish translocations, lake minnow, threatened species, threats to populations and habitats

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Introduction

Until recently, the lake minnow, *Eupallasella (Rhynchocypris) percnurus* (Pallas, 1814), was classified as a cyprinid species. According to present knowledge, it is classified as a representative of the family Leuciscidae within the order Cypriniformes (Schönhuth et al. 2018). This inconspicuous fish (Fig. 1) has a world-wide range of occurrence extending across Northern Eurasia from the Oder River basin in Poland to the Pacific Ocean in the Far East (Kusznierz et al. 2017). Globally, the lake minnow is not a threatened species (Kottelat and Freyhof 2007), nor is it considered endangered enough to be included in the latest edition of the European Red List of Freshwater Fishes (Freyhof and Brooks 2011). In contrast, the ecological status of the lake minnow in Poland is quite different, because populations have long been known to be at risk of extinction (Rolik and Rembiszewski 1987, Witkowski 1992, Kusznierz et al. 2005). The decisive factor is the specificity of its habitats, which disappear since most are small, shallow, artificial water bodies with a life-span limited to several decades (Wolnicki and Radtke 2009, 2010). Consequently, in Poland the lake minnow is a species under strict protection that requires active protection

Figure 1. Lake minnow individuals trapped in Dręszew in 2021 before the extinction of the population in 2023 (Photograph: Jacek Wolnicki).

measures to be implemented (Kaczmarczyk and Wolnicki 2016, Wolnicki and Sikorska 2022).

At present, lake minnow sites in Poland are known to exist in six voivodeships including Mazowieckie Voivodeship (Wolnicki et al. 2019, Wolnicki and Sikorska 2020). This part of the country was regarded previously as an important lake minnow region because of the richness of peat and clay deposits that were exploited widely by local communities (Wolnicki et al. 2011, 2022). The excavations, in particular those resulting from peat extraction, are the most common type of habitat for lake minnow populations in Poland (Wolnicki and Radtke 2009). However, it is believed that none of the historical Mazovian sites identified in the twentieth century have survived into the twenty-first century (Wolnicki and Sikorska 2009).

Among all the voivodeships with lake minnow sites, Mazowieckie Voivodeship is unique since it is where the first Polish project of active lake minnow protection was initiated and implemented. The long-term project was entitled "Conservation of lake minnow *Eupallasella perenurus*[1] populations in the area of Mazowsze" and began in 2002 (Wolnicki et al. 2006, 2008) and continued for 14 years (Wolnicki and Sikorska 2020). It had three major objectives: (a) to identify all existing but previously unknown lake minnow sites, (b) to locate suitable water bodies for translocation without requiring revitalization, (c) to identify strong local lake minnow populations that could serve as a source of fish for controlled breeding. The fourth goal was the controlled breeding of broodstock and the rearing their progeny to obtain juveniles for translocations. Quite

[1] The former scientific name pernurus was later replaced with the valid name percnurus.

recently (2017–2018) another conservation project limited to the area of Mazowiecki Landscape Park (Natura 2000 Special Area of Conservation Bagno Całowanie PLH140001) in the vicinity of Karczew was conducted with the same major goals as those mentioned above (Wolnicki and Sikorska unpubl. data).

The aim of the present work was to assess the efficiency of all active protection measures implemented to date in Mazowieckie Voivodeship to conserve the present and future occurrence of lake minnow in this part of Poland.

Study area

Large areas of today's Mazowieckie Voivodeship are known to have many smaller or larger peat and clay excavation sites that were dug in the twentieth century (Wolnicki et al. 2008, 2011, 2022). Many of these excavations have survived to the present, although the vast majority are in poor condition and filled with mud or are extremely shallow and overgrown with reeds and submerged macrophytes. Extensive field inventories undertaken in the early twenty-first century included almost 130 of these water bodies, and special attention was paid to any sites where lake minnow populations seemed likely to occur. The primary part of the study area was within a 40-km radius of the capital city of Warsaw in central Poland and included Karczew, Legionowo, Marki, Otwock, Radzymin, Wołomin, and Zielonka. Some field investigations were undertaken in more distant places near Gostynin, Płock, Sierpc, and Nowe Miasto nad Pilicą; however, all locations were within the voivodeship. Almost all of the places mentioned here were in the natural range of lake minnow occurrence in this part of the country based on many documented field observations from the twentieth century (Lorec and Wolski 1910, Dybowski 1916, Gąsowska and Rembiszewski 1967, Rolik and Rembiszewski 1987, Kusznierz 1995, 1996), some contemporary reports (Ligięza and Wolnicki 2003, Kusznierz et al. 2005, Wolnicki et al. 2006, 2007, 2008, 2011, Wolnicki and Radtke 2009), and many personal communications primarily from local anglers and other members of local communities.

Material and methods

Fish catches

In the early years of the original voivodeship conservation project, fish occurrence in water bodies was determined by angling or lift nets (Wolnicki et al. 2011). Beginning in 2005, only specialized baited traps were used (Kusznierz 2010), and these became the standard fishing tool for all investigations of this species (Wolnicki 2021, Wolnicki et al. 2022). Fishing was conducted during warm, calm weather from May to August. Trap exposition time was usually about 0.5 h, and the number deployed in a water body (5–10) depended on the water surface area. When no lake minnow individuals were caught in the traps, one or two or more attempts were always made in the same year or in the next. All lake minnow individuals caught were released back into their native water body immediately after capture. The only exception were mature fish that would be used as broodstock for captive breeding. The traps proved to be efficient tools for also catching fishes other than the lake minnow, including native or alien predatory species, so the results of fishing always provided a good picture of local fish community composition. This knowledge was helpful for including or excluding water bodies from further consideration of their potential usefulness for lake minnow translocation. Fish breeding and rearing

From 2004 to 2010, the lake minnow broodstock originated from a large population found in a mid-forest lake called Kręgulec (52°29'31.5" N; 21°16'16.2" E). This population became extinct in 2011–2012 because of a very strong increase in water acidification from formerly safe values of 5.1–6.9 pH (Wolnicki et al. 2008) to 4.2–4.4 pH, which is outside of the lake minnow range of tolerance (Wolnicki et al. 2015). All further broodstock

Table 1
Lake minnow sites established in Mazowieckie Voivodeship by translocation of juveniles in 2004–2018 and their present status (November 2024)

Name of the site	Geographical situation		Year of translocation	Number of translocations	Number of translocated fish (individuals)	Present status and year of last verification	Origin of the water body/Reason for extinction
	latitude	longitude					
Dobczyn	52°22'32.5"	21°19'09.5"	2009	1	400	ne (2012)	Likely former clay excavation/Habitat and population loss from reconstruction of the water body
Dręszew	52°30'11.3"	21°19'02.2"	2009	1	1000	ne (2023)	Former peat excavation/Habitat and population loss from drying up
Działy Czarnowskie	52°28'46.0"	21°14'52.0"	2004-2013	6	7870	ne (2019)	Likely small natural lake/Population extinction caused by introduction of predatory fish species: native *Esox lucius* L. and alien invasive *Ameiurus nebulosus* (Lesueur)
Kowalicha	52°30'28.2"	21°15'19.0"	2004-2006	3	1530	ne (2020)	Former peat excavation/Habitat and population loss from drying up
Lasków	52°29'38.1"	21°19'45.2"	2009	1	400	e (2024)	Former peat excavation/-
Łojków	51°30'02.0"	20°40'50.0"	2007-2008	2	3300	e? (2024)	Likely former peat excavation/-
Okuniew	52°16'03.9"	21°17'42.1"	2007-2011	3	1680	ne (2013)	Former artificial fire reservoir/Population extinction caused by introduction of alien invasive fish species: *Pseudorasbora parva* (Temminck & Schlegel) followed by *Perccottus glenii* Dybowski
Janów[1]	52°03'40.0"	21°17'51.0"	2012	1	160	e (2024)	Former peat excavation/-
Warszówka[1]	51°59'07.7"	21°20'24.8"	2017-2018	1	720	e (2024)	Former peat excavation/-

e – existent site; e? – likely existent site; ne – non-existent site; [1] Natura 2000 Special Area of Conservation Bagno Całowanie PLH140001.

activities were continued using a young but large population from a nearby site in Kowalicha that was created through fish translocations in 2004–2006 (Table 1). Shortly before its extinction from the lake drying up that occurred most likely in 2020 (Fig. 2a–2b), this population was found to have relatively high genetic variation compared to the majority of Polish populations that had existed for longer periods of time (Kaczmarczyk and Wolnicki 2016).

Lake minnow broodstock fish were caught in traps at the end of April or in early May, just before their natural spawning period. From 20 to 40 mature females and 15–20 males were used for captive breeding (Wolnicki et al. 2008, 2011). More females than males were always collected because this species is a batch spawner (Hliwa et al. 2017). This biological feature is a considerable impediment to synchronizing ovulation in females prepared for reproduction, while sperm is produced in large amounts without any stimulation over long periods (Wolnicki et al. 2015).

Lake minnow larvae were obtained using techniques for propagation and egg incubation developed specifically for this species (Kamiński et al. 2004, 2006). Eggs released by a single female were fertilized with mixed semen taken from 9–11 males and incubated at the optimum water temperature of 22°C while attached to glass plates placed in flow-through aquaria (Wolnicki et al. 2015). Larvae and juveniles were reared under controlled conditions to ensure their fast growth and good biological quality (Wolnicki et al. 2004, Kamiński et al. 2005). The fish

that were translocated were primarily juveniles aged 0+, although some older individuals aged 1+ were also used. Each year 1,000 to 4,000 fish were available for translocation.

Selection of habitats for fish translocation

The selection of water bodies for lake minnow translocation was based on two major criteria: (a) safe maximum water depth in summer of not less than 1 m measured in July/August, (b) absence of predatory fish species. Water bodies devoid of fishes were excluded from further consideration if the reason for this state was unclear or unknown. The vast majority of the several dozen water bodies examined were found to be entirely unsuitable for lake minnow translocation (Wolnicki et al. 2015). The most common drawback was insufficient maximum water depth in the summer that considerably limited water retention during long periods without adequate precipitation throughout the year. Predatory fish species such as native northern pike, *Esox lucius* L., or the invasive alien Amur sleeper, *Perccottus glenii* Dybowski, were noted in the water bodies very seldom. A total 13 individual water bodies, all inhabited by non-predatory cypriniforms – most commonly the alien gibel carp *Carassius gibelio* (Bloch), or its hybrids with native crucian carp *Carassius carassius* (L.) – were selected as they were appropriate for translocations.

Fish translocation

The first fish were translocated in 2004 into the previously mentioned water body in Kowalicha and Działy Czarnowskie; the last translocations were in 2017–2018 (Table 1). Lake minnow juveniles aged 0+ were usually translocated in late August or September when they weighed not less than 0.5–1 g. Rarely, attempts were made to use older (1+) and larger (2–3 g BW) fish for translocations in April and May. This was to allow sexually mature fish to spawn naturally in water bodies. Translocations were performed once or repeatedly. The number of fish translocated to a water body was generally as high as possible, according to recommendations for animal translocations (IUCN/SSC 2013), with regard to the size of the water body and of populations of co-occurring fish species. The number of fish released in a single translocation ranged from 160 to almost 2,000.

Results

In the 2004–2018 period more than 21,000 lake minnow juveniles were translocated into 13 water bodies to initiate new populations in Mazowieckie Voivodeship. Monitoring catches performed in the years after translocation confirmed lake minnow occurrence in nine of these sites (Table 1), while no lake minnow was confirmed in the other four water bodies.

According to the results of the latest monitoring conducted in 2021–2024, there are at most four new lake minnow sites in the voivodeship; among them two in the Natura 2000 network. To create them about 17,000 juvenile individuals were used. In most cases, a single translocation proved to be sufficient to effectively initiate sustainable new populations. The reasons of the ultimate disappearance of five sites that had existed sometimes for more than a decade following translocation were quite clear; these populations became extinct because of habitat loss in Dobczyn, Dręszew (Fig. 2a–2b) and Kowalicha (Fig. 3a–3b) or because of predatory fish species introduced into the water bodies by local anglers (Działy Czarnowskie, Okuniew).

Discussion

Old lake minnow sites in the voivodeship

It seems very likely that large parts of today's Mazowieckie Voivodeship were significant lake minnow areas of occurrence in previous centuries (Wolnicki et al. 2011, 2022). However, our knowledge about this will always remain scant, because

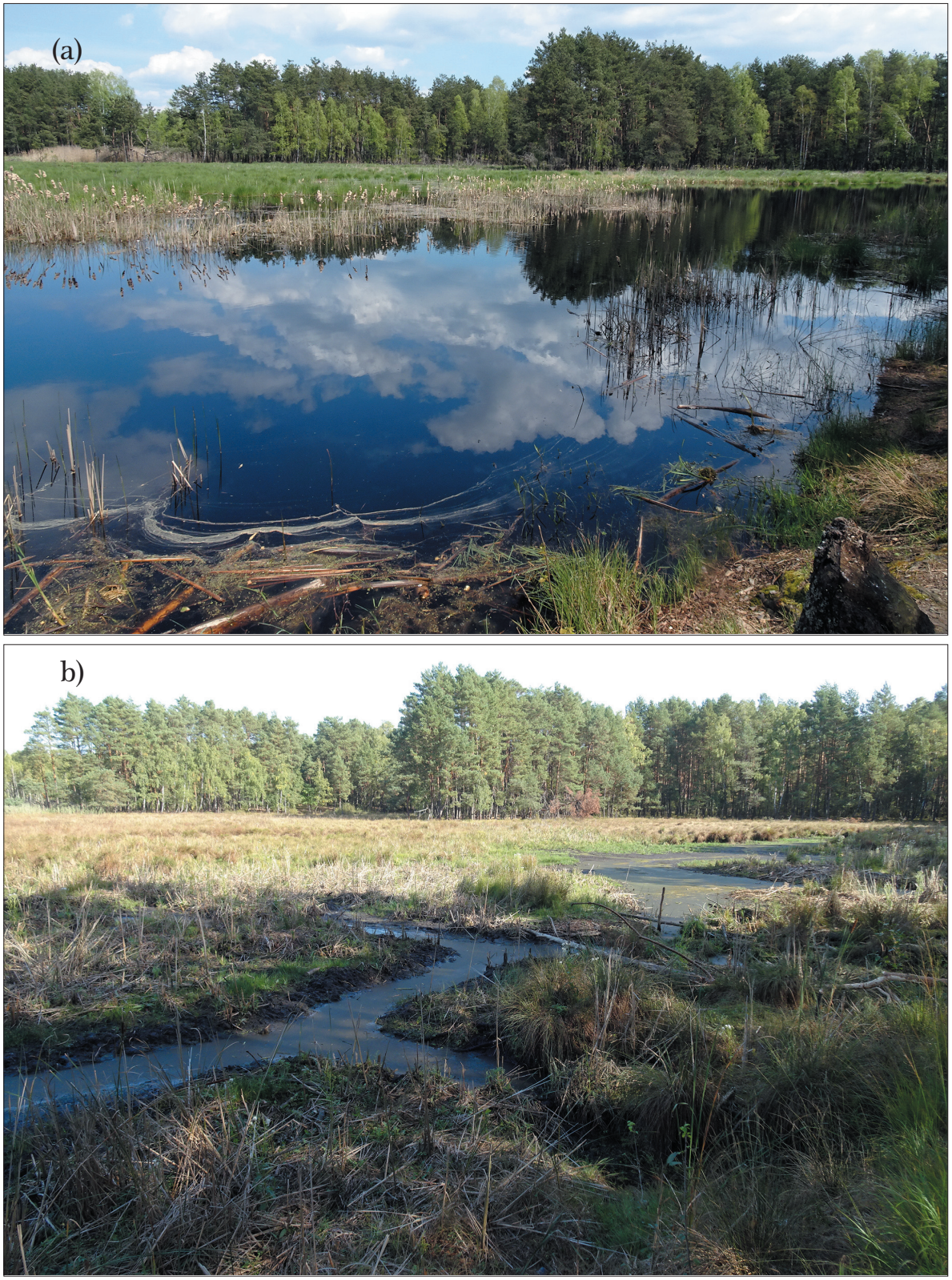

Figure 2. Non-existent lake minnow site Dręszew established through fish translocation. Its condition in 2017 (a) and after habitat disappearance in 2023 (b) (Photograph: Jacek Wolnicki).

Figure 3. Non-existent lake minnow site Kowalicha established through fish translocation. Its condition in 2018 (a) and after habitat disappearance in 2020 (b) (Photograph: Jacek Wolnicki).

Table 2
Lake minnow sites discovered in Mazowieckie Voivodeship in the early twenty-first century and their present status (November 2024)

Name of the site	Geographical situation		Year of discovery	Year of last verification	Present status	Reason of disappearance
	latitude	longitude				
"Bagno Jacka" Nature Reserve	52°15'20.3"	21°12'57.0"	2008	2012	ne	Population extinction due to increase in water acidification (pH < 5.0)
Białe Błota 1 [1]	52°21'30.6"	21°13'38.7"	2005	2024	e	-
Białe Błota 2 [1]	52°21'21.4"	21°13'47.5"	2005	2023	ne	Habitat and population loss from drying up
Bledzewo	52°49'37.6"	19°34'47.4"	2010	2024	ne	Population extinction probably due to habitat loss from temporal drying up
Glinianka[2]	52°29'32.4"	21°15'25.2"	2002	2024	ne	Habitat and population loss from drying up
Gostynin	52°26'06.4"	19°27'08.5"	2005	2012	ne	Population extinction due to unknown reason
Kręgulec[2]	52°29'31.5"	21°16'16.2"	2002	2021	ne	Population extinction due to increase in water acidification (pH < 5.0)
Nadma	52°21'18.7"	21°10'03.7"	2009	2024	e?	-
Nowiny	52°22'37.5"	21°13'01.0"	2007	2023	ne	Habitat and population loss from drying up
Zielonka[3]	52°17'45.3"	21°08'23.0"	2006	2024	e	-

e – existent site; e? – likely existent site; ne – non-existent site; Natura 2000 Special Area of Conservation: [1] Białe Błota PLH140038; [2] Krogulec PLH140008; [3] Strzebla błotna w Zielonce PLH140040.

comprehensive field surveys were not conducted until the early twenty-first century (Wolnicki et al. 2008, 2011). It is noteworthy that Dybowski (1916) and Lorec and Wolski (1910) published the first records of the occurrence of lake minnow in Mazowieckie Voivodeship. Dybowski described the highly probable, although not definitively confirmed, presence of this fish in a vanishing peat ditch in Warsaw in 1878, which is the oldest published record of lake minnow occurrence in Poland, whereas, in 1906 and 1909, Lorec and Wolski found two other sites that appeared to be small, old peat excavations. By the end of the twentieth century, only eight other sites throughout the large area of today's voivodeship were included in literature sources by Gąsowska and Rembiszewski (1967), Rolik and Rembiszewski (1987), and Kusznierz (1995), and one additional site near Wołomin was reported by Kusznierz (1998). These 12 sites disappeared before 2000 (Wolnicki and Sikorska 2009). Consequently, the belief that the lake minnow was absent from the area of today's Mazowieckie Voivodeship was widespread.

However, as early as 2002 two formerly unknown lake minnow sites, Glinianka and Kręgulec, were discovered near Radzymin in the vicinity of Warsaw (Ligięza and Wolnicki 2003; Table 2). Although it seemed very likely that they were the only Mazovian lake minnow sites, these new discoveries provided the stimulus for organizing more extensive searches. Field inventories began shortly afterwards, and more than 100 water bodies were monitored. They were situated in the vicinity of Warsaw in all areas where lake minnow sites had existed in the past or were most likely to occur (Wolnicki et al. 2011). Six previously unknown sites were discovered during field work in 2005–2008 (Wolnicki et al. 2006, 2008), and yet another was discovered in 2009 (Table 2). By the end of the decade, the total number of existing sites in the voivodeship was nine (Wolnicki et al. 2011).

Importance of new lake minnow populations in the voivodeship and in Poland

In 2011, in addition to the nine sites mentioned above, the existence of seven other populations newly established by fish translocation was

Table 3
Assessment of threats to lake minnow habitats and populations in Mazowieckie Voivodeship in November 2024

Name of the site	Habitat	Population
Old sites		
Białe Błota 1 [1]	Moderate risk; relatively safe water depth	Moderate risk of extinction due to habitat loss; low risk of predatory fish introductions by anglers because of periodically hindered access to the water surface
Nadma*	High risk of drying up due to shallowing	High risk of extinction due to possible habitat loss
Zielonka[2]	High risk of drying up due to shallowing despite partial deepening in 2022	High risk of extinction due to possible habitat loss
New sites created by translocation		
Lasków	High risk of drying up due to shallowing	High risk of extinction due to possible habitat loss
Łojków*	Moderate risk; relatively safe water depth	Moderate risk of extinction due to habitat loss; moderate risk of predatory fish introduction by anglers because of periodically hindered access to the water surface
Janów[3]	High risk of drying up due to shallowing	High risk of extinction due to possible habitat loss
Warszówka[3]	Moderate risk; relatively safe water depth	Moderate risk of extinction due to habitat loss; moderate risk of predatory fish introduction by anglers

* Presence of lake minnow needs to be confirmed; Natura 2000 Special Area of Conservation: [1] Białe Błota PLH140038; [2] Strzebla błotna w Zielonce PLH140040; [3] Bagno Całowanie PLH140001.

confirmed (Wolnicki et al. 2011). The total number of 16 lake minnow sites in the voivodeship was the highest ever confirmed in this region of Poland. The new sites constituted almost 44% of all those in the voivodeship. Shortly afterwards, however, both new and old lake minnow sites started to disappear, including three old sites in the protected Natura 2000 network (Table 2). The loss of the only two lake minnow sites in the Special Area of Conservation (SAC) Krogulec PLH140008 is particularly significant since the SAC was established to protect this particular species. Consequently, of the four Mazovian SACs established for protecting lake minnow in the voivodeship, only three remain (Wolnicki et al. 2022).

The disappearance of lake minnow sites has been accelerated considerably by the permanent hydrological drought caused by climate change. The most common reason for habitat loss has been water bodies drying up (Tables 1 and 2), whereas several populations rapidly became extinct following the introduction of predatory fish species. In the late fall of 2024, only three or four new populations were known to exist (Table 3). However, they play a considerable role in the lake minnow inhabiting the voivodeship, where the total number of sites decreased to a maximum of seven. It is also worth underlining their notable role in Poland since the total number of lake minnow sites in Poland is currently assessed to be just 80–90 (Wolnicki and Radtke unpubl. data); this is in comparison to less than two decades ago when there were 160–170 sites (Wolnicki and Radtke 2009 and unpubl. data).

Prospects for the lake minnow in Mazowieckie Voivodeship

In Poland, the active protection of the lake minnow was initiated almost 20 years ago in Mazowieckie Voivodeship (Wolnicki et al. 2008). At that time fish translocations alone seemed the most appropriate lake minnow protection measure as it was both inexpensive and easy to implement. However, despite undertaking protective measures of this kind thus far, the disappearance of Mazowieckie Voivodeship lake minnow sites is progressing (Wolnicki et al. 2022, 2024). In the meantime, it has become obvious that the prerequisite for success in active lake minnow

protection is revitalizing its disappearing habitats prior to fish translocation. Sayer et al. (2020) drew the same conclusion from the early results of the first English conservation project for the endangered cyprinid crucian carp, *Carassius carassius*. It should be mentioned that, in Poland, lake minnow and crucian carp quite frequently cohabit the same disappearing habitats, where they are exposed to the same threats such as ponds drying up from drought, filling in, and finally becoming dry land. Moreover, predation of native or alien predatory fish species can often pose a serious threat to populations of both species.

The revitalization of lake minnow habitats thus far has proved effective in Lubelskie (Polesie National Park, Natura 2000 Special Area of Conservation Ostoja Poleska PLH060013; Wolnicki et al. 2018, 2022, Wolnicki and Sikorska 2020) and Wielkopolskie voivodeships (SAC Barłożnia Wolsztyńska PLH300028; Wolnicki and Sikorska 2019, 2023). However, it has only been effective for limited periods of several years. In Mazowieckie Voivodeship only one lake minnow habitat has been revitalized to date in the SAC Strzebla Błotna in Zielonce PLH140040 (Wolnicki and Sikorska 2022). Lake minnow translocation to this revitalized water body was not necessary because a relatively large population of this species was still present in it (Wolnicki 2021 and unpubl. data).

None of the protection measures applied thus far in Poland have proved to be efficient enough to stop or at least slow down the process of disappearing lake minnow sites. According to very recent observations, all lake minnow sites in Mazowieckie Voivodeship are generally subject to the risk of disappearance (Table 3). Four sites are at high risk of drying up, and habitat revitalization is urgently needed. Only three water bodies at the sites of Białe Błota 1, Łojków and Warszówka seem to be moderately safe since they retain water better compared to the other sites. However, these three sites are periodically accessible to anglers. This could mean they are at danger from introductions of predatory fish species, which is a practice that has become increasingly common in Poland in recent years, and one that always results in the extinction of lake minnow populations (Wolnicki 2021 and unpubl. data, Wolnicki et al. 2022).

In light of the facts discussed above, it cannot be surprising that the future of the lake minnow in Mazowieckie Voivodeship is cause for considerable concern, irrespective of the origin or age of the particular habitats or populations. It seems that among the present Mazovian sites, only the four that are protected within the Natura 2000 network have a real chance of surviving (Wolnicki et al. 2022) provided active measures for habitat protection are implemented in time. However, in contrast to the revitalization of lake minnow habitats, there are no means that can effectively counteract illegal introductions of predatory fish species or at least significantly mitigate the negative effects of them (Wolnicki et al. 2022). This leads to the conclusion that, in the worst case, lake minnow populations might not survive in Mazowieckie Voivodeship despite all past, present, and future protection efforts.

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Authors contributions. J.S. investigation, writing original draft, reviewing and editing. J.W. concept, investigation, writing original draft, reviewing and editing. Both authors approved the manuscript for publication.

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