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# New records of alien monkey goby, *Neogobius fluviatilis* (Pallas, 1814), in the waters of the Great Masurian Lakes system (north-eastern Poland)

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## Abstract

The invasion of aquatic environments by alien fish species is an important issue in ecological research. Alien fish species, such as Ponto-Caspian gobies, can impact native communities and ecosystems through predation, competition, parasite vectors, disturbance, and habitat modification. In this study, we present new locations of monkey goby *Neogobius fluviatilis* in the waters of the Great Masurian Lakes system (north-eastern Poland). Four methods (Nordic gillnets, electrofishing, fishing rod, and Vulkan crayfish trap) were used for fishing. The presence of *N. fluviatilis* was recorded in nine lakes of different morphometry and trophic status, one canal, and at one site of the Pisa River in 2018–2020. Total length and body weight of *N. fluviatilis* were rather small (42–113 mm; mean of 81 ± 19 mm and 0.3–13.7 g; mean of 6.4 ± 3.6 g, respectively). The most specimens were in the range of 80 to 100 mm. Our study documented that *N. fluviatilis* inhabits lakes, rivers and canals. The invasion of *N. fluviatilis* into the Great Masurian Lakes system occurred across the Pisa River from the Narew River. In the Great Masurian Lakes, the northernmost place in the system in which *N. fluviatilis* was recorded was Lake Niegocin. We may expect that *N. fluviatilis* can quickly spread farther, reaching lakes situated in the northern basin of the system in the near future.

**Key words:** invasion, fish, lakes, canals, rivers

## Introduction

The invasion and dispersal of non-native or alien species is a global problem that has attracted a considerable amount of research over the past several decades (Bollens et al. 2002). Most aquatic non-indigenous species are transported long distance by different dispersal mechanisms and vectors, including rain, flowing water, animals, natural or anthropogenic movement of water and sediments (ships' ballast waters/sediments), movement and intentional release of aquaculture, fishery, bait species, and pet industries or management practices (Ruiz et al. 1997; Bailey et al. 2003; Grabowska et al. 2009).

Invasive species that establish successful populations often have strong impacts on aquatic ecosystems through various processes including predation,

disturbance, habitat modification and competition (Grabowska et al. 2009). They may alter food web structure, ecosystem functioning, water quality, and may lead to the reduction of diversity in native communities (Hall and Mills 2000; Ricciardi and MacIsaac 2011; Villéger et al. 2017; Rösch et al. 2018). Strong negative impacts of invaders on native species appear to be more frequent in freshwater ecosystems than in marine habitats (Ricciardi and Kipp 2008). It is documented that alien invasive fish can cause genetic introgression and hybridisation, destruction of spawning grounds and habitats for many freshwater organisms, reduced reproduction success of native species due to predation on eggs and offspring as well as transfer of parasites and diseases (Kostrzewa and Grabowski 2003; Grabowska and Grabowski 2005; Kakareko et al. 2005; Grabowska et al. 2010; Kvach et al. 2014; Volta et al. 2018). In addition, alien fish species can cause a trophic cascade resulting in increased algal biomass and production and altered energy and nutrients flow (Simon and Townsend 2003).

The monkey goby, *Neogobius fluviatilis* (Pallas, 1814), is a small benthic fish species naturally inhabiting freshwater, estuarine and coastal ecosystems of Black Sea, Sea of Azov, Caspian Sea and their rivers (Miller 2003). *Neogobius fluviatilis* prefers sandy, gravel and rocky bottoms (Danilkiewicz 1998; Erős et al. 2005; Jurajda et al. 2005; Płąchocki et al. 2020; Top et al. 2019). This species is able to prey on a variety of food, including insect larvae and pupae, crustaceans, annelids, gastropods and fish, among which chironomids are preferentially grazed (Adámek et al. 2007; Grabowska et al. 2009). *Neogobius fluviatilis* is a typically invasive species expanding its range of occurrence in Europe through three main invasion corridors (Bij de Vaate et al. 2002; Copp et al. 2005; Roche et al. 2013). The northern corridor includes the Volga River, the Rybinsk Reservoir and lakes Ladoga and Onega and is connected by artificial canals with the Gulf of Finland. The central corridor includes rivers Dnieper and Pripyat that are connected with the Vistula River system, while the southern corridor includes the Danube River to the Rhine River (Neilson and Stepien 2011).

In Poland, *N. fluviatilis* was found for the first time in September 1997 in the Bug River (the tributary of Vistula River) (Danilkiewicz 1998). In subsequent years, this species was recorded in the Vistula River along its course to the mouth of Gdańsk Bay, in the Bug River along its entire length within Polish borders, and in the Narew River and its tributaries (Kostrzewa and Grabowski 2002; Kostrzewa et al. 2004; Kakareko et al. 2005; Grabowska et al. 2009, 2010; Semenchenko et al. 2011; Lejk et al. 2013; Grabowska and Przybylski 2015; Szlakowski et al. 2019). The occurrence of this species has been reported in the waters of the Great Masurian Lakes system (Kapusta et al. 2020; Pawelec-Olesińska 2020), but there is no detailed information about the distribution of *N. fluviatilis* in this area. In Polish inland waters, three other alien goby species, such as round goby *Neogobius melanostomus* (Pallas, 1814), racer goby *Babka gymnotrachelus* (Kessler, 1857) and western


**Figure 1.** Map of the Great Masurian Lakes system (north-eastern Poland) with all the studied sites marked (blue names) and sites (red circles) where *N. fluviatilis* were found. Red arrow indicates migration way.

tubenose goby *Proterorhinus semilunaris* (Heckel, 1837), have been recorded so far (Kostrzewa et al. 2004; Sapota 2004; Grabowska et al. 2008, 2010, 2021). All these gobies have Ponto-Caspian origins and naturally inhabit brackish waters of Black, Azov and Caspian Sea and their rivers (Miller 2003).

The aim of the study was to present newly colonized habitats by alien *N. fluviatilis* in the Great Masurian Lakes system (north-eastern Poland).

## Materials and methods

### *Study sites*

The study was conducted in lakes, canals and rivers of the Great Masurian Lakes system situated in north-eastern Poland (Figure 1). Basic morphometric and trophic characteristics of the studied lakes are presented in Table 1.

**Table 1.** Morphometric and trophic characteristics of the studied lakes. SDD – Secchi disc depth, TSI – trophic state index, * – lakes in which *N. fluviatilis* were recorded.

| Lake | Area (ha) | Mean depth (m) | Max. depth (m) | SDD (m) | TSI | Trophic status |
|---|---|---|---|---|---|---|
| Pogubie Wielkie | 670.8 | 1.0 | 2.6 | 0.35 | 75.15 | Hypereutrophy |
| Pogubie Małe | 60.3 | 1.3 | 2.5 | 0.22 | 81.84 | Hypereutrophy |
| Jegocin | 122.0 | 9.0 | 36.1 | 4.50 | 38.30 | Mesotrophy |
| Nidzkie* | 1818.0 | 6.2 | 23.7 | 0.90 | 61.52 | Eutrophy |
| Guzianka Duża* | 59.6 | 6.5 | 25.5 | 0.90 | 61.52 | Eutrophy |
| Warnołty* | 337.8 | 2.3 | 5.3 | 0.38 | 73.96 | Hypereutrophy |
| Krutyńskie | 50.9 | 2.5 | 5.2 | 1.70 | 52.34 | Meso-eutrophy |
| Gardyńskie | 82.6 | 2.4 | 11.5 | 1.40 | 55.15 | Eutrophy |
| Mikołajskie* | 497.9 | 11.2 | 25.9 | 1.95 | 50.37 | Meso-eutrophy |
| Tałty* | 1160.4 | 15.6 | 44.7 | 1.80 | 51.52 | Meso-eutrophy |
| Ryńskie* | 670.8 | 10.0 | 50.8 | 1.10 | 58.62 | Eutrophy |
| Jagodne* | 942.7 | 8.7 | 37.4 | 1.10 | 58.62 | Eutrophy |
| Boczne* | 183.3 | 8.7 | 17.0 | 1.80 | 51.52 | Meso-eutrophy |
| Niegocin* | 2600.0 | 10.0 | 39.7 | 2.20 | 48.62 | Meso-eutrophy |
| Dejguny | 765.3 | 12.0 | 45.0 | 4.00 | 40.00 | Mesotrophy |
| Kirsajty | 207.0 | 3.2 | 5.8 | 3.40 | 42.34 | Mesotrophy |
| Mamry | 2504.0 | 11.9 | 43.8 | 4.50 | 38.30 | Mesotrophy |
| Pozezdrze | 122.5 | 1.8 | 4.0 | 1.50 | 54.15 | Meso-eutrophy |
| Wilkus | 96.5 | 1.8 | 5.6 | 2.20 | 48.62 | Meso-eutrophy |

Trophic state index (TSI) of lakes was calculated from Secchi disc depth (SDD) according to Carlson (1977). The Great Masurian Lakes include three basins: northern basin drained by the River Węgorapa, central basin with no outflow and southern basin drained by the River Pisa. Lakes of the northern basin (Przystań, Mamry, Dargin, Łabap and Kisajno) are mainly mesotrophic. Most lakes in the central part of the system (lakes Niegocin, Boczne, Jagodne, Szymoneckie, Szymon, Tałtowisko) are meso-eutrophic, while lakes located in the southern basin (e.g. Ryńskie, Tałty, Mikołajskie, Śniardwy, and Bełdany) are eutrophic, including highly eutrophicated lakes (e.g. shallow lakes Szymon and Warnołty) (Bajkiewicz-Grabowska 2008). The lakes of this system are connected by natural and artificial channels or natural rivers and streams. They are typical postglacial, mainly surrounded by agriculture areas and forests (Ejsmont-Karabin et al. 2020). All lakes have a similarity in input of allochthonous mineral and organic matter due to comparable agricultural, wetland, and urban areas (Chróst and Siuda 2006). Most lakes are dimictic with distinct summer thermal stratification. In summer, the lakes are intensively used for tourism and fishing.

### *Fish sampling and identification*

Data were collected from 19 lakes, 2 canals and the Pisa River during spring–summer 2018–2020, using Nordic gillnets and electrofishing according to European standard protocols (EN 14757 and EN 14011, respectively). In addition, fish caught with crayfish Vulkan traps (Ulikowski et al. 2017) as well as fish caught and reported by anglers have been included (Supplementary material Table S1). All of the caught specimens of *N. fluviatilis* were identified and counted. Individual measurements of total length (TL) and weight (W) of all fish caught were determined with an accuracy of 1.0 mm and up to 0.1 g, respectively.

**Figure 2.** Photographs of *N. fluviatilis* from Lake Mikołajskie. Photograph by Dariusz Ulikowski.

*Neogobius fluviatilis* can be distinguished from other gobiid species by the following characteristics: (1) the space between the eyes is usually smaller than the diameter of the eye; (2) in the second dorsal fin, the height of the rays gradually decreases towards the tail; (3) the ventral fin usually extends to the anus (Biró 1971). Other characteristic features distinguishing *N. fluviatilis* from *B. gymnotrachelus* are the presence of scales on the head and the absence of a black spot on the dorsal fin which is characteristic for *N. melanostomus* (Kottelat and Freyhof 2007).

## Results

The specimens of *N. fluviatilis* (Figure 2) were found in nine lakes of different maximum depth (shallow and deep), surface area (small-sized and large-sized) and trophic status (meso-eutrophic, eutrophic and hypereutrophic), one canal and at one site on the Pisa River in 2018–2020 (Figure 1). A total of 77 individuals of *N. fluviatilis* were caught by different fishing gear. One individual only was caught in 4 lakes (Nidzkie, Ryńskie, Jagodne, and Niegocin) and in the Mioduński Canal (Table S1). The most specimens (45) were recorded in eutrophic Lake Mikołajskie. Total length (TL) ranged from 42 to 113 mm (mean of 81 ± 19 mm), while body weight (W) varied between 0.3 and 13.7 g (mean of 6.4 ± 3.6). Most specimens (32) were in the range of 80 to 100 mm (Figure 3), accounting for 41% of the total number of caught individuals.

## Discussion

In this paper, we present the new data documenting the distribution of the highly invasive *N. fluviatilis* in the Great Masurian Lakes system. In our study,

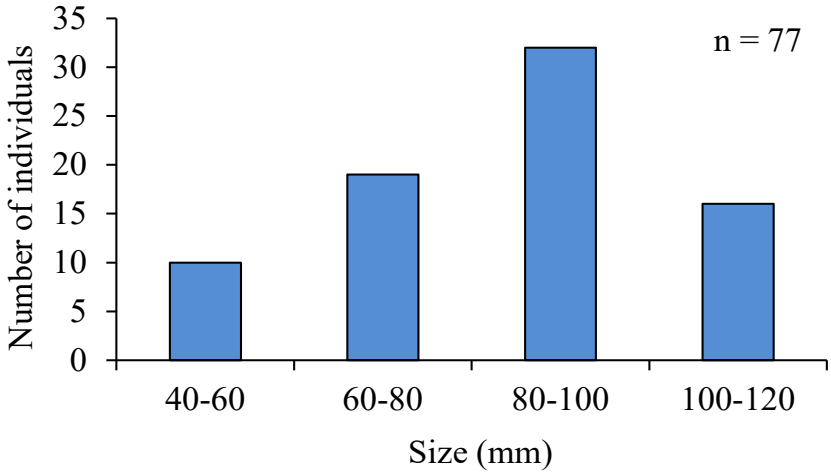


**Figure 3.** Size distribution of *N. fluviatilis*, in different total length (TL) ranges, found in nine lakes, one canal and Pisa River of the Great Masurian Lakes system.

specimens of *N. fluviatilis* did not exceed 113 mm in total length and body weight of 14 g. These values are within the range reported by other authors, who found that total length and body weight range from 32 to 152 mm and from 0.3 g to 34.0 g, respectively, depending on age class and season of the catch (Kostrzewa and Grabowski 2002; Lejk et al. 2013; Grabowska and Przybylski 2015). In the River Rhine, total length of the collected specimens ranged from 77 to 112 mm (Kessel et al. 2009). According to Kottelat and Freyhof (2007), maximum standard length (SL) is 200 mm.

Our study showed that *N. fluviatilis* expanded their range upstream into Pisa River and settled lakes and canals situated in the southern and central parts of the system. This indicates that this species inhabits both lentic (lakes) and lotic (rivers, canals) ecosystems. Initially, it was assumed that *N. fluviatilis* can spread to new areas not so fast as other gobies species, namely *N. kessleri* and *N. melanostomus*, due to its limited habitat preference to sandy and/or sandy-gravel bottom (Čápová et al 2008). However, it has been shown that the invasion of this species was favoured by species-specific features, such as extended spawning period, nesting and parental care (Grabowska and Przybylski 2015), or a wide range of diets and opportunistic feeding strategies (Kakareko et al. 2005; Grabowska et al. 2009).

The first 50 specimens of the Pontian monkey goby *N. fluviatilis* in Poland were caught in the middle of the Bug River near Janów Podlaski (a tributary of the Vistula River; Baltic Basin) in September 1997 (Danilkiewicz 1998). Five year later, in May 2002, eight individuals of this species were caught in the Włocławski Reservoir situated in the lower part of the Vistula River in Murzynowo (Kostrzewa and Grabowski 2002) and this was the first record from the Vistula River. In 2003, *N. fluviatilis* was found in the Zegrzyński Reservoir on the Narew River (Kostrzewa et al. 2004). It has been calculated that within seven years this species extended its range 836 km further to the mouth of the Vistula River, forming a stable population in the lower section of rivers Vistula and Bug in 2007–2008 (Grabowska et

al. 2009, 2010; Semenchenko et al. 2011). In 2007–2011, a total of 388 of *N. fluviatilis* were recorded in the Vistula River estuaries and the Vistula Lagoon (Lejk et al. 2013). In 2011–2018, *N. fluviatilis* was caught at 57 sites of the Vistula River (along its course, from the mouth of the Sanna River to the mouth to Gdańsk Bay) and the Bug River (along its entire length within Polish borders) and it spreads towards the north-east direction along the Narew River and its tributaries (Szlakowski et al. 2019). Probably, *N. fluviatilis* migrated to the Great Masurian Lakes system through the Pisa River, a tributary of the Narew River.

In Polish lakes, the first specimens (n = 40) of *N. fluviatilis* were caught in July–August 2014 in Lake Roś belonging to the Great Masurian Lakes system (Pawelec-Olesińska 2020). In our study, among the total of 19 studied lakes, *Neogobius fluviatilis* was recorded in 9 lakes of the Great Masurian Lakes system, differing in morphometry and trophy. Based on data in the available literature and those in our study it seems that the invasion of *N. fluviatilis* in Polish waters is progressing quickly, which is definitely influenced by its species characteristics. Broad environmental tolerance, high biological plasticity and opportunistic feeding are considered key factors facilitating the colonization of new waters and invasion success of this species (Kakareko et al. 2005; Grabowska et al. 2009; Karakus et al. 2018). It is documented that the mean rate of *N. fluviatilis* dispersal in Poland is 122 km per year (Semenchenko et al. 2011). Because lakes in the system of the Great Masurian Lakes are connected directly or by short natural or artificial channels as well as connected with rivers and streams we may expect that *N. fluviatilis* can quickly spread farther, reaching lakes situated in the northern basin of the system in the near future. The northern part of the Great Masurian Lakes belongs to the Pregolya River catchment area, therefore it can be assumed that this species will also spread to this river. However, further more detailed studies, including all lakes of the system, are required to prove our assumption. It is also interesting what changes will occur in the structure of the native fish community after the invasion of *N. fluviatilis*.

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**Supplementary material**

The following supplementary material is available for this article:

**Table S1.** Summary of records of *N. fluviatilis* in waters of the Great Masurian Lakes system (north-eastern Poland).

This material is available as part of online article from:
http://www.reabic.net/journals/bir/2021/Supplements/BIR_2021_Ulikowski_etal_SupplementaryMaterial.xlsx