



First Record of the Western Greece Goby *Economidichthys pygmaeus* (Gobiiformes: Gobiidae) in the Pinios River (Greece). Is it the First Freshwater Greek Endemic that will Spread to Eastern Europe?

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Abstract: Freshwater fish translocations (the movement of species across zoogeographical boundaries within the same country) are a largely overlooked issue regarding invasive species. This is the first record of a self-reproducing, translocated population of the Western Greece goby *Economidichthys pygmaeus* (Holly, 1929) in the Macedonia-Thessaly Ecoregion (Central-Eastern Greece). The species is known to spread rapidly throughout Greece from its native habitats in Western Greece (Ionian Ecoregion) over the recent decades. However, its small size and cryptic behaviour makes its detection challenging. *Economidichthys pygmaeus* survives in a wide range of temperatures, indicating a strong potential for survival if it spreads further north on the Balkans. The possible impacts of this invasive goby on native gobies include trophic competition and disease transmission.

Key words: Cryptic invasive fish, freshwater gobies, fish translocation, river ecology

Introduction

Non-native fish pose a significant threat to the native freshwater fish fauna in lakes and rivers globally (Reid et al. 2019). This issue becomes even more severe when non-native species are morphologically similar to the native ones, making early detection in new habitats challenging (Zogaris et al. 2023; Zogaris et al. 2024). Another growing threat is that of translocated species, species transferred

out of their native range or beyond biogeographical regions (Zogaris et al. 2009 for the freshwater ecoregions of Greece); with often understudied but also documented negative impacts on the native fauna and ecosystems (Perdikaris et al. 2016; Boon et al. 2020).

There are two native gobies of *Economidichthys* in Western Greece: the endangered Trichonis dwarf goby *E. trichonis* (Economidis & Miller 1990) and *E. pygmaeus* (Holly, 1929). The later spe-

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cies is not threatened in its native habitats and its conservation status is characterized as least concern (Economidis 2009; Van Oosterhout et al. 2022).

This relatively small goby (up to 6 cm in total length (TL) according to Barbieri et al. 2015) was originally known to occur as a range-restricted endemic in Western Greece (in the Ionian Ecoregion, Economidis & Miller 1990), specifically in Trichonis/Lysimachia Lake complex, on Lefkada Island, the Louros River Basin and the lower Amvrakikos Watershed. Later, it was recorded in the Southern Acheloos River Basin and in the Mornos River, where it exists as a genetically isolated population within the Ionian Ecoregion (Vanhove et al. 2012). By 2015, it was recorded in Pamvotida Lake, in the Kalamas and Arachthos River Basins in Western Greece and in the Peloponnese in the artificial Lake Taka. Within the Western Aegean Ecoregion (a clear translocation case), it was found in the Boeotian Kifissos River Basin and in the hydrologically connected lakes Yliki (Barbieri et al. 2015) and Marathon (Zogaris et al. 2024; Barbieri et al. 2015). In July 2016, it was recorded in the transboundary Lesser Prespa Lake (Van Oosterhout et al. 2022), while in August 2020 it was also found in the adjacent transboundary Larger Prespa Lake (Shumka et al. 2020) in the Southern Adriatic Ecoregion. Recently, it was identified in the Thrace freshwater Ecoregion (Aggitis sub-basin of the transboundary Strymon River, Zogaris et al. 2024).

The Pinios River Basin (Thessaly), where the Western Greece goby was first recorded in 2022, is located in Central Greece and is the second largest basin in Greece covering approx. 11,000 km², 42% of which are lowland (Vasiliades et al. 2011; Zogaris et al. 2009). The lowland section of the river hosts the native range-restricted and endangered Thessaly goby *Knipowitschia thessala* (Economou et al. 2007; Barbieri et al. 2015). Thessaly is the most intensively cultivated area in Greece with irrigation for agriculture taking up to 95% of the total water use, as well as hosting a large number of industries and other human activities (Matiatos et al. 2023a,b). The native fish fauna is threatened by diffuse and point source pollution, as well as habitat desiccation and river engineering for anti-flood and drainage works (Barbieri et al. 2015; Skoulikidis et al. 2022).

In this paper, we report on the translocation and establishment of a self-reproducing population of *E. pygmaeus* in the Litheos River, a perennial tributary of the Pinios River (Thessaly) flowing through the city of Trikala. In addition, we describe the identification process and discuss the conservation implications of our findings.

Materials and Methods

In May 2022, during a sampling within the frame of the implementation of the National River Monitoring Programme (2018-2023) for the WFD 2000/60, we conducted electrofishing in a 100-m section of the Litheos River following the European protocol CEN. The sampling was carried out by a four-member team with an electrofishing device (EFKO GmbH, Model FEG 6000, generator powered, unpulsed DC, 3.0 KW output power, 150-600 V). Upon capture, stunned fish were identified, measured, assigned to 5-cm-total-length (TL) classes and released back into the water. During the sampling, 39 gobies (37 < 5 cm and 3 > 5 cm) were collected (density 3.9 individuals/m²). Upon capture, gobies were examined macroscopically and tentatively identified as *K. thessala* (the native goby species). However, the unusually large size of many of the gobies (close to 5 cm), prompted us to euthanise 14 individuals with excess anesthetic (saturated clove oil solution) and to place them in 95% ethanol for further laboratory inspection. *Economidichthys pygmaeus* can be distinguished from their congener *E. trichonis* and from other gobies by the length of their peri-anal organ, which is at least half the length of the pelvic disk (Economidis & Miller 1990; Kottealt & Freyhof 2007).

Results

Upon detailed morphological examination in the laboratory, all gobies collected from the Pinios River Basin were identified as the Western Greece goby *E. pygmaeus*, based on the size of the characteristic peri-anal organ of males (Fig. 1a, b).

All individuals were adults displaying typical breeding colouration; males exhibited a dark grey or black colouration (Fig. 1), while the females were smaller, lighter in colour, with a yellowish tinge on the ventral side and a concentration of black melanophores on the lower part of the mandible (Fig. 2a, b).

Discussion

We report the presence of a self-reproducing population of Western Greece gobies based on the colouration and the size of the collected fish. More specifically, the female fish exhibited a characteristic colouration that has also been reported in fish of the related genus *Knipowitschia* (Massironi et al. 2005) and associated with fertility (Vanhove et al. 2012). This, as well the large size of the collected gobies, indicate that the fish are successfully reproducing in this tributary of the Pinios River.

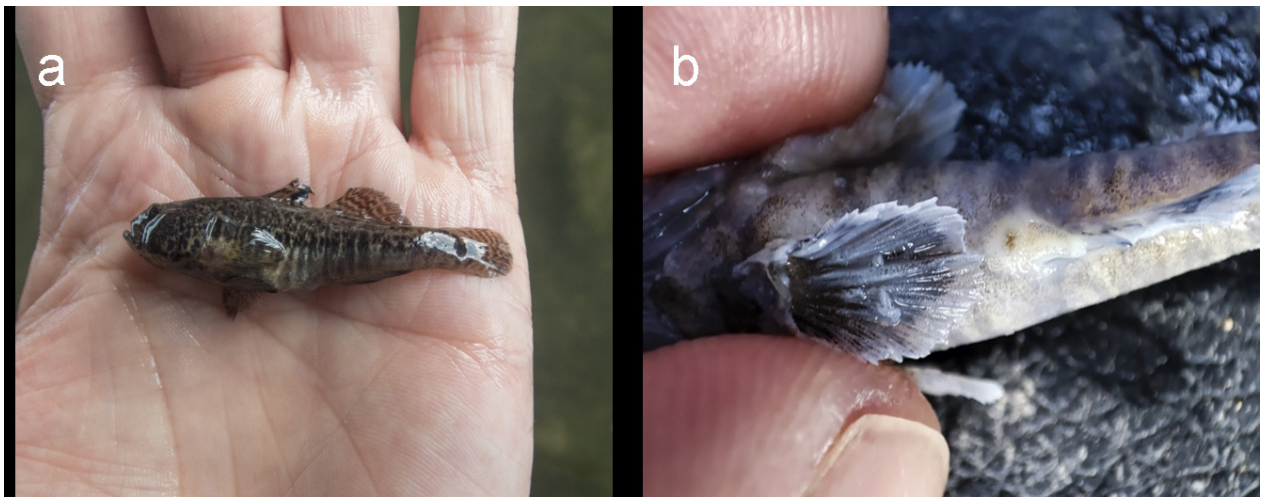


Fig. 1. Male goby specimens: (a) Live specimen (TL 6.1 cm), with black colouration; (b) Characteristic peri-anal organ of a specimen (in ethanol).

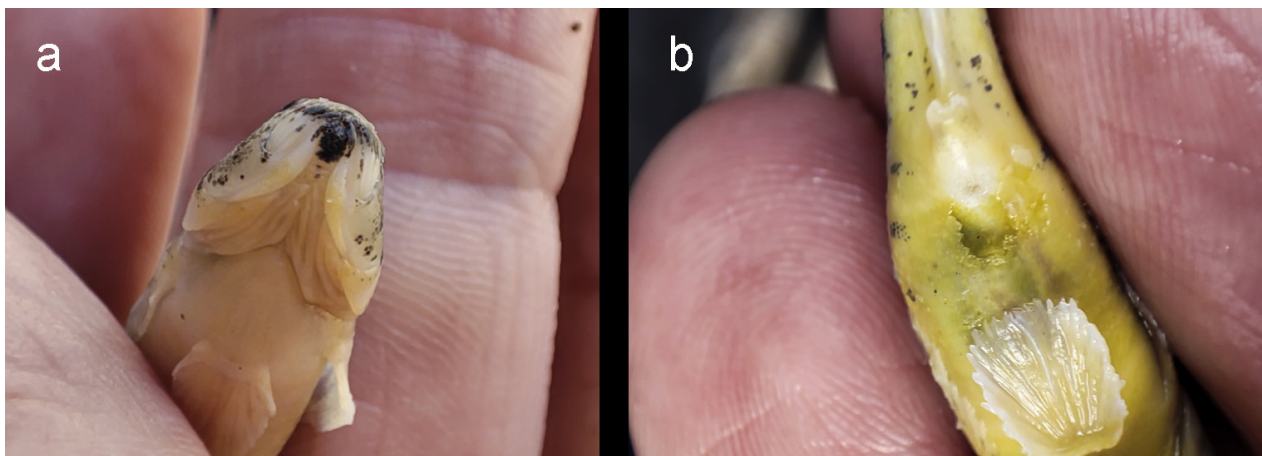


Fig. 2. Female goby specimens: (a) Specimen in ethanol; (b) Detail of the pelvic fin and anus area (in ethanol).

The Pinios River Basin has high fish species diversity, with 17 different species recorded so far and an average number of 12 fish species per water body in selected surveyed river segments (Vavalidis et al. 2021). At our sampling location in Litheos liver, the Western Greece gobies were found in association with *Cobitis vardarensis* (Karaman, 1928), *Pachychilon macedonicum* (Steindachner, 1892), *Barbus sperchiensis* (Stephanidis, 1950), *Squalius vardarensis* (Karaman, 1928) and *Rhodeus meridionalis* (Karaman, 1924) which indicates that these translocated gobies can survive and reproduce in the highly diverse habitats of the Pinios River Basin. It seems that the Western Greece goby has steadily spread to almost all ecoregions of mainland Greece (Fig. 3). There may be several explanations for this rapid spread and several logical hypotheses may be proposed. For example, its presence in the Yliki Lake in Eastern Greece may be due to the artifi-

cial connection of the Mornos River Basin (Central Greece) with the Yliki Lake and the Marathon Lake (in the outskirts of Athens) for the water supply of multimillion inhabitants of the city. In other areas that are not hydrographically connected, unintentional transport by humans is the more probable reason. Translocation may also be related to transport of aquatic plants or gravel containing eggs, as this species, unlike other gobies, has not been found to build nests (Gkenas et al. 2010), instead it lays its eggs in cavities of submerged reeds (Daoulas et al. 1993). Several authors have noted that the spread of this and other translocated species may be a consequence of unintended secondary introduction through stocking events, particularly with fry of *Cyprinus carpio* (Economou et al. 2004). Nearly all previous publications agree that the translocations are wholly anthropogenic and do not involve natural distribution extensions.

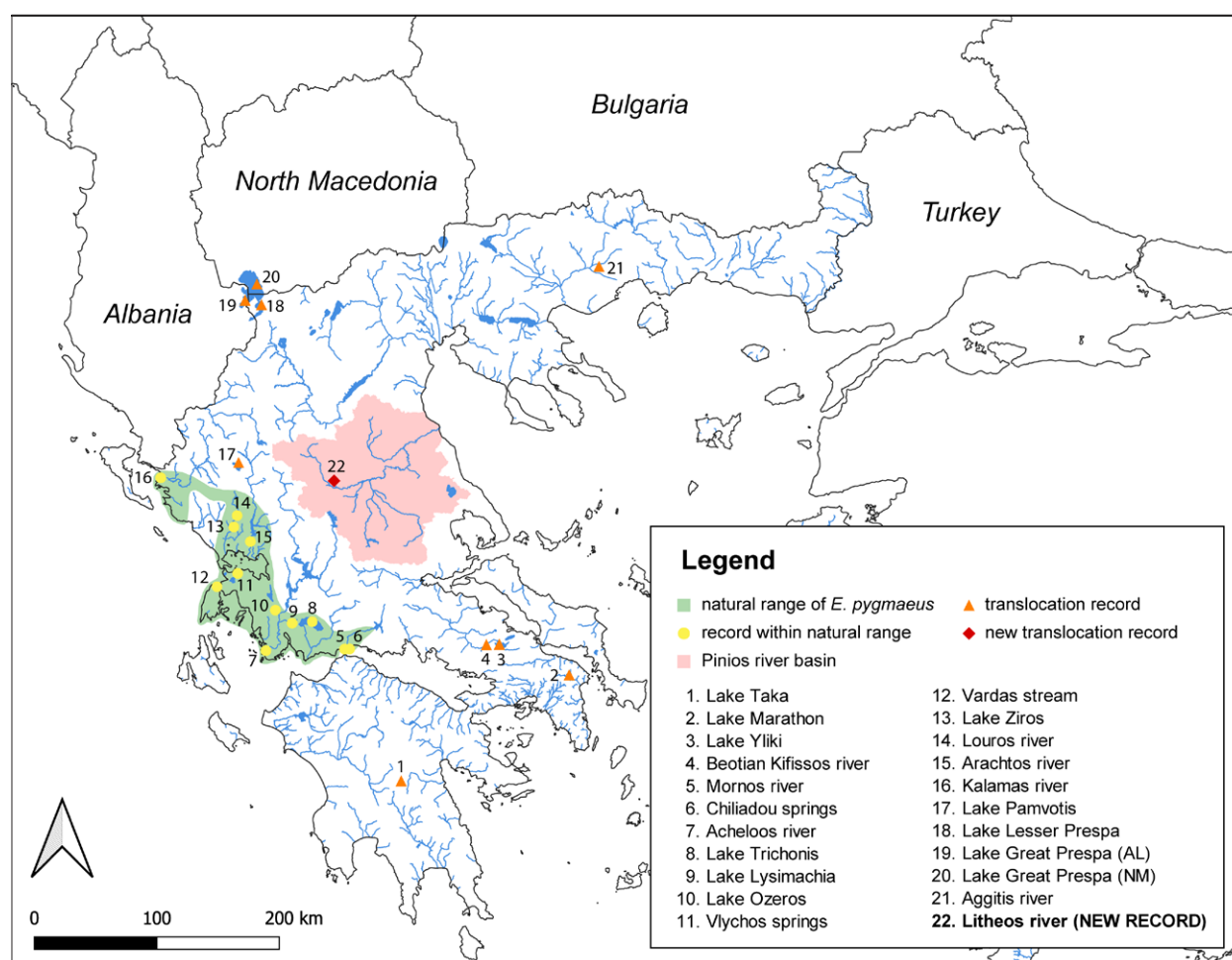


Fig. 3. The areas and hydrological basins where *E. pygmaeus* has been found until today.

Currently there are no reports on the possible impacts of the translocated goby on the indigenous fish fauna of Greece. However, given that the species has been identified in two transboundary lakes (Prespa Lakes) of the South-East Adriatic Ecoregion (Van Oosterhout et al. 2022, Shumka et al. 2020) and more recently in the Thrace Ecoregion (Strymon River Basin: Zogaris et al. 2024), we believe that care should be taken to prevent its spread further north to the Balkans and in the Danube River Basin. Its native range in Western Greece includes the Trichonis and Lysimachia Lakes that are low altitude lakes that do not freeze in the winter. However, the presence of *E. pygmaeus* in the Prespa Lakes and in the Strymon Basin in Northern Greece indicates that the species can tolerate lower temperatures than the ones in its area of origin. The average temperature in Trichonis Lake is 18°C (min 13°C - max 21°C), while the average temperature in Megali Prespa is 14°C (min 2°C - max 18°C) (HCMR, 2023, Network of automatic monitoring stations of water resources, <https://hydro-stations.hcmr.gr/>).

The increase in temperature in Europe due to climate change in conjunction with the degradation of freshwater ecosystems may lead to the movement further north of the Western Greece goby as well as several other Mediterranean thermophilic fish species.

Due to its small size and cryptic behaviour the species is not easily detected. Therefore, we believe that its spread already in other Balkan ecoregions cannot be excluded. Thus, we suggest rigorous monitoring both with conventional electrofishing techniques, as well as monitoring through environmental DNA (eDNA) use, a non-invasive, cost-effective molecular technique that relies on the detection of DNA traces from tissues of organisms in their water, a method that has been used in recent years to find rare native and/or alien fish in the rivers of Greece (Kalogianni et al. 2023a, b).

Data on the environmental impact of this goby in the habitats it has been translocated are lacking. Will the presence of *E. pygmaeus* have a negative effect on the population of the endangered Pinios goby

K. thessala? Although both species are called small sand gobies and occupy similar habitats, we have no indication that *E. pygmaeus* will be a direct threat to *K. thessala*, as *E. pygmaeus* has been found to coexist with another indigenous species of *Knipowitschia* in Lake Trichonis ((Daoulas et al. 1993). The species is predatorily active most intensively between 2 am and 8 am, indicative of its cryptic behaviour (Gkenas et al. 2011). We know that it is mainly carnivorous and feeds on small invertebrates, such as crustaceans with copepods being the most important food source, insects, molluscs, as well as plants, all indicative of a trophic plasticity that could confer to the species having an advantage versus native gobies, as inferred for other alien gobies in the Sava River basin (Jakovlić et al. 2015). Furthermore, a behavioural study on the interactions of the Western Greece goby with native gobies could provide additional information on the potential negative impacts of the species on native species through aggression or habitat exclusion. Attention should be given to the potential impacts of the invasion of the species in new aquatic systems through the introduction of endoparasites, as it has been demonstrated that *E. pygmaeus* are often carriers of parasites such as *Gyrodactylus* sp. (Vanhove et al. 2014). Therefore, it is crucial to further investigate and assess the impacts of this species in terms of disease transmission.

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