Int. J. Aquat. Biol. (2026) 14(5): 11-25
ISSN: 2322-5270; P-ISSN: 2383-0956
Journal homepage: www.ij-aquaticbiology.com

Original Article

Aquarium fish invasions in Türkiye's lakes and rivers: Assessing risks and consequences

Burak Seçer[1], Sevil Sungur*[2], Gökhan Kalayci[3], Fatih Polat[4], Emre Sezer[4], Halil Günay[5], Deniz İnnal[4]

[1]Hana Re-De and Consultancy Ltd., Kapadokya Teknopark, Nevşehir, Türkiye.
[2]Department of Biology, Faculty of Art and Sciences, Nevşehir Haci Bektaş Veli University, Nevşehir, Türkiye.
[3]Recep Tayyip Erdoğan University, Fisheries Faculty, Rize, Türkiye.
[4]Department of Biology, Faculty of Art and Sciences, Burdur Mehmet Akif Ersoy University, Burdur, Türkiye.
[5]Serik Forest Management Directorate, Serik, Antalya, Türkiye.

Abstract: The introduction of non-native aquarium fish into freshwater ecosystems has become an increasing problem in Türkiye. Owing to the rapid growth in the introduction of non-native aquarium fish, there is a need to assess their dispersal, monitor their ecological impacts, and develop management methods to prevent further introductions. Recent findings have confirmed the introduction of 14 species of aquarium fish into some of the country's rivers and lakes. Eleven of which are invasive, and the Climate Change Assessment (CCA) and Basic Risk Assessment (BRA) scores of these species are high. Ornamental fishes are distributed throughout the water basins of Türkiye. Introductions are mainly human-induced, often due to pet owners dumping unwanted aquarium fish into the wild without regard for their ecological implications. The species that have been introduced have been found in aquatic ecosystems such as slow-flowing rivers, lakes, and dams, and have the potential to develop sustainable populations. The ecological risks that result from introductions include competition and predation among local fauna and species, interbreeding, habitat modification, and the transfer of diseases and parasites. This study aims to investigate the dispersal of introduced aquarium fish in Türkiye's freshwater aquatic ecosystems, considering their ecological impacts.

Article history:
Received 4 April 2026
Accepted 29 May 2026
Available online 25 October 2026

Keywords:
Ornamental fish
Aquarium
Global climate change
Endemic fish

Introduction

Aquariums are a staple of the aquatic sciences sector and serve as significant venues for observing, conserving, and educating about aquatic biodiversity. Aquariums are ideal laboratories for a vast scope of biological research inquiries and offer excellent conditions for studying a vast array of subjects like reproductive biology, growth and developmental patterns, feeding habits, behavioral ecology in fish, the effect of water quality on the health and physiology of fish, components of stress, and disease control (Wedemeyer, 1996). Aquariums also play a significant conservation role by participating in breeding endangered species and releasing them into their natural habitats, thereby contributing to biodiversity enrichment (Rhyne et al., 2017). Aquariums have also served as educational tools, informing the general public about the need for environmentally responsible fishing and the challenges facing aquatic ecosystems (Reid et al., 2013; Murchie et al., 2018).

In addition to the scientific benefits, it has become a hobby for a wide audience interested in fish. The aquarium industry has evolved into a significant global market, with millions of marine and freshwater species being collected annually for both recreational and commercial purposes. This sector includes a wide range of products necessary for the establishment and maintenance of both private and public aquariums, including live fish, corals, and various aquatic plants (Leal et al., 2015; Rhyne et al., 2017; Dalavi and Pawar, 2023). The wider economic gain for the aquarium trade extends from the sale of living organisms to the sale of auxiliary products such as

*Correspondence: Sevil Sungur
E-mail: sevilsungur@nevsehir.edu.tr

DOI: https://doi.org/10.22034/ijab.v14i5.2886

aquarium tanks, filtration systems, and specialized feeds, and therefore helps toward a healthy supply chain that local economies can gain from (Leal et al., 2015; Dalavi and Pawar, 2023). Moreover, a greater preference among aquarium keepers for sustainably oriented methods has driven demand for species harvested responsibly. This further improves the economic sustainability of local fishing and aquaculture practices (Rhyne et al., 2012; Leal et al., 2015). In this regard, aquariums serve as a main link between mankind and aquatic ecosystems, while also driving economic development through the production and commercialization of a wide array of aquarium-related products (Raghavan et al., 2018; Dalavi and Pawar, 2023).

Historical sources indicate that the Sumerians cultivated fish for culinary purposes around 2,500 years ago (Altınköprü, 1983; Geldiay, 1985). Subsequently, evidence has emerged that the Romans practiced fish husbandry during the 1st century AD, utilizing glass containers to maintain aquatic life. This development is widely regarded as a significant precursor to modern ornamental fishkeeping. The first forms of the modern goldfish (*Carassius auratus*) emerged in the 7th century, with significant developments occurring in China during this period. Goldfish were domesticated and kept in ponds and decorative porcelain containers. Following this period, goldfish breeding and selective breeding spread rapidly, and goldfish reached Europe a few centuries later. By the 12th century, the Chinese had developed goldfish varieties in various colors, and in the 17th and 18th centuries, European writings included observations on feeding fish in glass containers and their lives. By the 19th century, a variety of such specimens had been produced, including those with double tails, telescope eyes, and dorsal-finless individuals (Innes, 1948; Axelrod and Schultz, 1955; Altınköprü, 1983; Geldiay, 1985; Türkmen, 1995).

Interest in aquarium fishkeeping in Türkiye first emerged in Istanbul after the First World War and subsequently reached its greatest popularity in the 1950s. This assertion is further supported by the observation that a significant proportion of families residing in major cities such as Istanbul, Ankara, and Izmir owned aquariums (Baytop, 1961; Türkmen, 1995). The growing global popularity of ornamental fish in the second half of the 20th century was also observed in Türkiye (Altinköprü, 1983; Geldiay, 1985; Türkmen, 1995). Greater access for hobbyists in Türkiye to exotic ornamental fish, such as goldfish, guppies, and cichlids, has come through enhanced transport and foreign trade. Concurrently, enhanced aquarium technology, such as filtration, aeration equipment, and specialized fish feed, has led to healthier conditions and lower mortality rates, thereby sustaining demand and enabling many species to be successfully bred. Furthermore, urbanization and rising standards of living have led to the emergence of a new middle-class consumer group interested in aesthetic leisure and aesthetic pieces for the home and work environment. This has also generated increased demand for ornamental fish. Turkish aquarists have also formed local clubs and societies, published articles in specialized magazines, and organized exhibitions. These initiatives have seen strides in knowledge exchange and in sensitizing the community among enthusiasts. Universities and research institutions have also registered increased scholarly interest in freshwater aquaculture and ornamental fish farming, reflecting monetary and ecological concerns related to trade. Aquarium fishkeeping in Türkiye has therefore advanced from a specialist leisure activity to a popular one and a small sector of the pet trade, reflecting developments observed worldwide (Altinköprü, 1983; Geldiay, 1985).

Nevertheless, this rising trend in keeping aquarium fish has also had various ecological impacts on inland water habitats. Aquarium fish, along with commercial globalization and the development of hobby aquarium keeping, have become among the most widely transported species by humans, far beyond their natural distribution areas. It is estimated that 80% of the more than 5000 freshwater fish species traded globally are of exotic origin, with a significant proportion released or escaping into freshwater systems for various reasons (Welcomme, 1988; Duggan et al., 2006). Numerous species of aquarium fish have been introduced into aquatic ecosystems worldwide. The introduction of fish species into aquatic ecosystems by humans has significant ecological consequences. The deliberate or unlawful introduction of non-native species poses a significant threat to aquatic biodiversity (Singh and Lakra, 2011). For instance, in the state of Kerala, India, aquarium fish such as *Poecilia reticulata*, *Xiphophorus hellerii*, and *Pterygoplichthys* species have established permanent populations in river systems as a result of religious rituals known as "mercy releases" (Krishnakumar et al., 2009). A study conducted by Duggan et al. (2006) in Canada found that 72% of the species sold in 20 aquarium stores had previously been recorded in the country's inland water habitats. It has been demonstrated that species with high economic value and widespread sales are more likely to be transported to habitats and establish themselves in the wild (Rixon et al., 2005).

In Türkiye, the presence of species introduced into the country through the ornamental fish trade, particularly through escapes from ornamental ponds and fish farms, has been documented in natural waters (Mousavi-Sabet and Eagderi, 2016; Çiçek et al., 2022; Mosavi-Sabet et al., 2023a, b). In Türkiye's inland waters, which are highly endemic, there has been a notable increase in sightings of non-native aquarium fish. Such introductions are frequently the result of intentional releases, accidental escapes from aquaculture facilities, or the release of fish by hobbyists that are no longer viable for release into the wild. This situation poses significant risks, including competition for resources with native species, predation on local fauna, genetic hybridization that threatens genetic integrity, and the potential spread of pathogens and parasites not previously present in the ecosystem (Radkhah et al., 2016, 2022; Mousavi-Sabet et al., 2023).

The first documented occurrence of exotic aquarium fish in Türkiye's freshwater systems was reported in research conducted in the latter half of the 20th century. The earliest record of ornamental fish in freshwater systems of Türkiye dates to the 1940s, with *Gambusia holbrokii*. In the later years *P. reticulata*, *X. hellerii*, *Hemichromis letourneuxi*, *Pangasius sanitwongsei*, *Pygocentrus nattereri*, *Lepomis gibbosus*, *Oreochromis niloticus*, *Tilapia zillii*, etc. as numerous exotic aquarium fish species have appeared in freshwater bodies and irrigation channels in Türkiye (Altinköprü, 1983; Geldiay, 1985; Yalçın Özdilek, 2007; Emiroğlu et al., 2016; Yoğurtçuoğlu and Ekmekçi, 2018; Türkmen, 2019; İnnal and Sungur, 2019; Kırankaya and Ekmekçi, 2021; Çiçek, 2021; Çiçek et al., 2021). Ecological concerns regarding species' benthic feeding behavior, which disrupts benthic structure and increases turbidity in aquarium water, are significant (Çiçek et al., 2021). These cases highlight the importance of systematic observation and control of the ornamental fish trade and underscore a delicate balance between cultural practices and conservation needs in Türkiye, a country with extremely high, highly diverse aquatic biodiversity and a high level of endemism.

The increasing popularity of the aquarium trade has led to a growing number of records of aquarium-origin fish species in freshwater ecosystems, raising serious concerns about biodiversity conservation in Türkiye’s inland waters, which are characterized by high endemism and ecologically sensitive habitats. Of the 428 freshwater fish species reported from Türkiye to date, 215 (50.4%) are endemic, and 21 (4.9%) are alien, highlighting the vulnerability of these ecosystems to biological invasions (Çiçek et al., 2023). Under these circumstances, there is a need for comprehensive assessments of aquarium-origin fish that integrate nationwide evaluations with up-to-date field observations.

Hence, the current study provides a country-scale assessment of non-native aquarium fish reported from Turkish freshwater ecosystems and documents recent occurrences of *P. reticulata, X. maculatus,* and *X. hellerii* in the Sarıkavak Stream (Serik, Antalya). These records demonstrate that the introduction of aquarium fish is not solely a historical phenomenon but remains an ongoing issue across Türkiye, underscoring the need for continuous monitoring, early detection, and risk-based management strategies to safeguard highly sensitive, endemically rich freshwater systems.

Materials and Methods

The study was prepared from literature reviews of published papers, reports, and working papers, as well as samples from the Sarıkavak Stream in the Serik district of Antalya Province, on the distribution and biology of aquarium species (aquatic ornamental fish) in natural and altered aquatic systems of Türkiye. Current data for each species have been included. In addition, the invasiveness potential of the species examined was screened using the Aquatic Species Invasiveness Screening Kit (AS-ISK). AS-ISK is a screening tool established for detecting potential ecological damage to aquatic organisms and is available online (www.cefas.co.uk/nns/tools/). Screening was conducted through a joint evaluation of literature data and expert knowledge. According to literature reviews, 14 species were examined within the scope of AS-ISK (Tarkan et al., 2017). Within this scope, this study has conducted risk assessments for species that had not yet appeared in the literature on this topic, taking into account their zoogeographical location, microclimatic conditions, and ecological tolerance parameters. In addition, to enhance the scientific validity of the answers to the 55 questions within the scope of the analysis, related articles, reports, and theses have been examined in detail. Answers for the five questions concerning climate data have been provided using the Köppen-Geiger climate classification system and climate change-related reports and articles (Peel et al., 2007; Demir et al., 2008; Anonymous, 2015). A Climate Change Assessment (CCA) score was obtained for each species, in addition to the Basic Risk Assessment (BRA). Based on the scores obtained, the examined species have been ranked into one of three risk levels: 'high', 'medium', or 'low'. The criterion value used to determine those categories was 27.75, as reported by Tarkan et al. (2017).

In addition to literature reviews and AS-ISK evaluations, field studies were also conducted. A field sampling was conducted on 13 April 2025 at the Sarıkavak Stream in the Serik district of Antalya Province, Türkiye, located at coordinates 37.14631279°N and 30.92604128°E. Fish specimens were collected during these ichthyological surveys and subsequently subjected to morphological and molecular genetic identification. Morphological examinations and molecular analyses were carried out in the laboratories of the Department of Biology, Faculty of Science and Arts, Burdur Mehmet Akif Ersoy University, and the Faculty of Fisheries, Recep Tayyip Erdoğan University, Rize, Türkiye.

DNA isolation, PCR, and sequence analysis for genetic identification of samples: Genomic DNA was extracted from the fin tissue of samples stored in pure ethanol. The DNA extraction was performed using the Qiagen DNeasy Blood & Tissue Kit according to the manufacturer's instructions on the Qiacube Automatic DNA Extraction Instrument. Polymerase chain reaction (PCR) was performed on the Bio-Rad Thermal Cycler using the mitochondrial cytochrome c oxidase subunit I (COI) gene universal barcoding primers LCO1490 and HCO2198 (Folmer et al., 1994). The PCR reaction conditions and component volumes were detailed in Akhan et al. (2014).

The raw data from sequence analysis were edited by visually inspecting the peaks using BioEdit 7.2.5 (Hall, 1999). Sequence similarity searches were conducted using both the BLAST tool in the NCBI database (http://www.ncbi.nlm.nih.gov) and the Barcode ID engine in the BOLD Systems database. For molecular identification and phylogenetic analysis, 15 COI barcodes from the study area were compared with publicly available NCBI Reference sequences for the species *P. reticulata* (NC 024238), *X. helleri* (NC 013089), and *X. maculatus* (NC 011379.1). *Oreochromis niloticus* (NC013663) was chosen as the outgroup taxon for rooting the phylogenetic tree. MEGA 11 (Tamura et al., 2021) software was used for the nucleotide substitution model and Maximum likelihood (ML) analysis. The nucleotide substitution model HKY+G was selected for ML analysis.

Results

To date, a total of 14 exotic species have been intentionally or incidentally introduced to Türkiye's freshwater fish basins. Of these, five species were introduced for aquaculture/research, two for the development of fisheries to augment natural stocks, two for biological control, and seven for aquarium fisheries (Çiçek et al., 2023). Although some species have been introduced into Turkish waters for other purposes, such as biological control or fish stocking, they are species used worldwide as ornamental fish and have potential that could be exploited in Türkiye. The introduced species were revised using literature sources, Türkiye's current list of inland fish species, and various database records. As a result, there are 14 ornamental fish species belonging to five orders and eight families (Table 1, Fig. 1).

Within the scope of the present study, 9 individuals of *P. reticulata*, 5 individuals of *X. hellerii,* and one individual of *X. maculatus* were identified genetically

Table 1. Current list of ornamental fish species in inland waters of Türkiye.

No	Orders	Families	Species	Common name	Recorded basins
1	Centrarchiformes	Centrarchidae	*Lepomis gibbosus*	Pumpkinseed	1-2-3-4-5-6-7-8-12
2	Cichliformes	Cichlidae	*Coptodon rendalli*	Redbreast tilapia	18
3	Cichliformes	Cichlidae	*Coptodon zillii*	Redbelly tilapia	8-9-10-17-18-19-20
4	Cichliformes	Cichlidae	*Oreochromis aureus*	Blue tilapia	17-18-19-20
5	Cichliformes	Cichlidae	*Oreochromis niloticus*	Nile tilapia	17-18-19-20
6	Cypriniformes	Cyprinidae	*Carassius auratus*	Goldfish	1-2-17-18-19-20
7	Cypriniformes	Gobionidae	*Pseudorasbora parva*	Topmouth gudgeon	1-2-3-4-5-6-7-8-9-10-11-12-13-14-15-16-17-18-20-21-22-24
8	Cyprinodontiformes	Poeciliidae	*Gambusia holbrooki*	Eastern mosquitofish	All River Basins
9	Cyprinodontiformes	Poeciliidae	*Poecilia reticulata*	The guppy	5-21
10	Cyprinodontiformes	Poeciliidae	*Xiphophorus hellerii*	Green swordtail	21
11	Cyprinodontiformes	Poeciliidae	*Xiphophorus maculatus*	Southern platyfish	9
12	Siluriformes	Clariidae	*Clarias batrachus*	Philippine catfish	12
13	Siluriformes	Loricariidae	*Pterygoplichthys disjunctivus*	Vermiculated sailfincatfish	12-19
14	Siluriformes	Loricariidae	*P. pardalis*	Amazon sailfin catfish	12

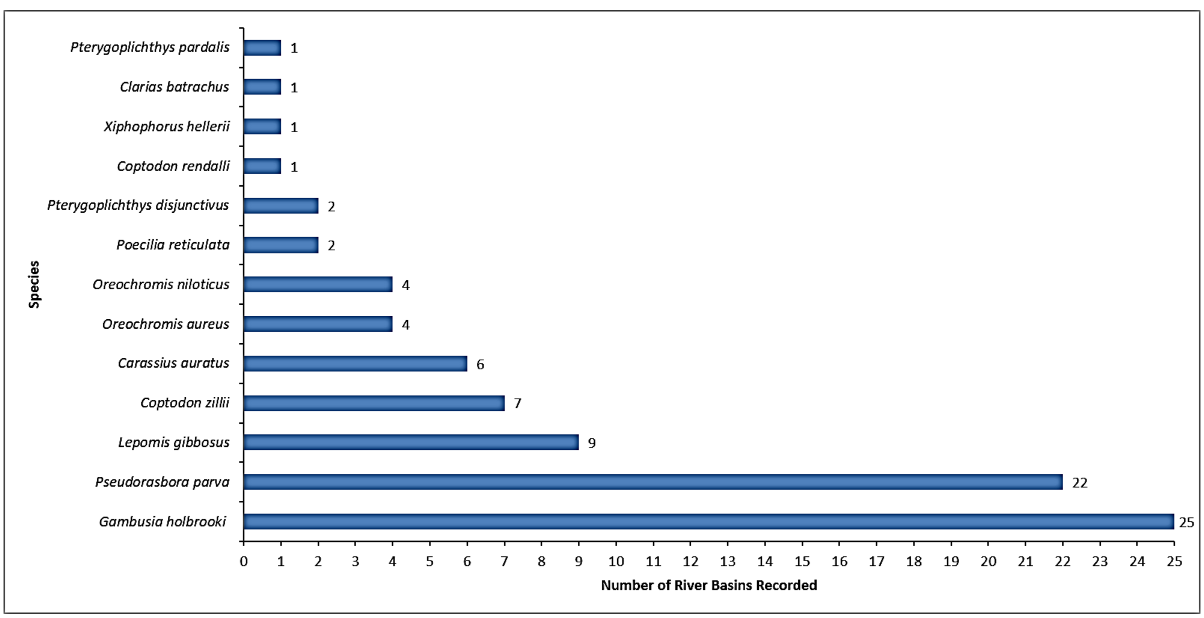

Figure 1. Basin occurrence of ornamental species across 25 river basins

from Sarıkavak Stream in the Serik district of Antalya Province. The NCBI Nucleotide BLAST and BOLD Barcode ID similarity index of these samples was calculated to be more than 95%. According to phylogenetic analysis, the species were resolved as monophyletic within NCBI reference sequences, with high bootstrap support (Fig. 2).

Türkiye is divided into 25 river basins numbered and named as; 1-Meriç-Ergene, 2-Marmara, 3-Susurluk, 4-Kuzey Ege, 5-Gediz, 6-Küçük Menderes, 7-Büyük Menderes, 8-Batı Akdeniz, 9-Antalya, 10-Burdur, 11-Akarçay, 12-Sakarya, 13-Batı Karadeniz, 14-Yeşilırmak, 15-Kızılırmak, 16-Konya, 17-Doğu Akdeniz, 18-Seyhan, 19-Asi, 20-Ceyhan, 21-Fırat-Dicle, 22-Doğu Karadeniz, 23-Çoruh, 24-Aras, and 25-Van Lake. *Gambusia holbrooki* were reported in all basins, and *Pseudorasbora parva* were reported in 22 basins, suggesting they are almost universally distributed across the region. A second group of species—such as *Lepomis gibbosus, C. zillii,* and *C. auratus*—shows moderate levels of spread, occurring in several basins and forming broadly established populations. Meanwhile, other species, including *O. niloticus, O. aureus, P. reticulata, Pterygoplichthys* spp., *Clarias batrachus, X. hellerii*, and *Coptodon rendalli*, appear in only a few basins, which may reflect more recent introductions, limited establishment, or early stages of spread.

Aquarium fish are at high risk of contributing to global biological invasions. These species are particularly favored for their small size, aesthetic appeal, low maintenance costs, and high commercial value. Due to their tolerance to low oxygen levels, they rapidly expand their distribution area and increase water turbidity by scraping sediments in benthic areas, reduce photosynthetic light transmittance, and destroy the spawning grounds of native species by eliminating habitat complexity (Çiçek et al., 2022; Mousavi-Sabet et al., 2023a). This also increases the likelihood that they will be introduced to new habitats and become invasive. The invasive success of these species is often associated with their broad environmental tolerance and high adaptability.

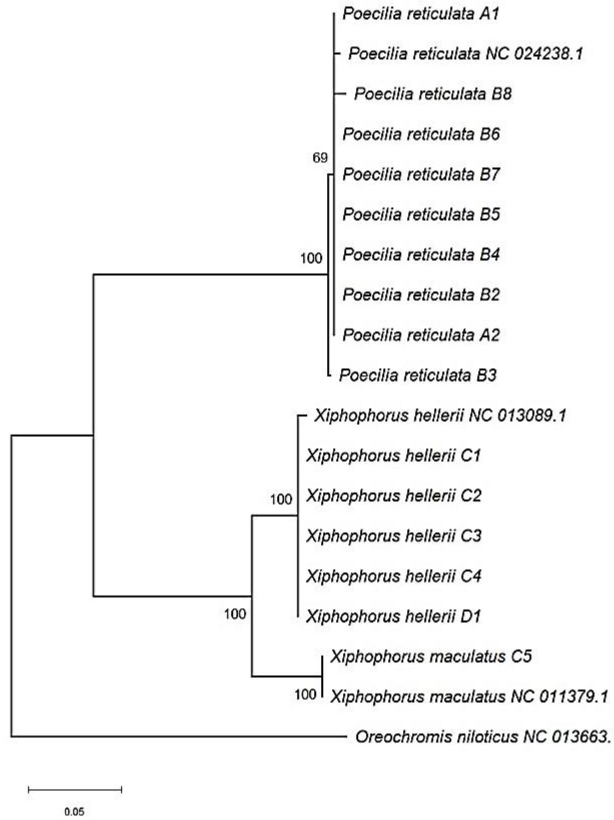

Figure 2. Maximum Likelihood (ML) phylogenetic tree of ornamental fish species in Sarıkavak Stream, Antalya, Türkiye.

The scores and status of the species evaluated within the scope of AS-ISK are given in Table 2 and Figure 3. Employing the Basic Risk Assessment (BRA) scores, 10 out of the 14 species were classified as 'highly invasive,' while the remaining five were considered 'moderately invasive.' However, when climate change factors were accounted for using the Climate Change Assessment (CCA) scores, 13 of the 14 species were rated as 'highly invasive', with the remaining two still falling under the 'moderately invasive' category. These results clearly suggest that climate change significantly increases the invasion potential of aquarium fish.

Most of the species assessed come from tropical and subtropical regions, meaning they are naturally less suited to adapt to Türkiye’s temperate ecosystems. Yet, due to Türkiye’s diverse geography, many regions contain hot-water sources, creating microhabitats ideal for these species. A prime example is *C. batrachus*—one of the world’s 100 most dangerous invasive species—establishing itself in the

Table 2. The scores and status of the species evaluated within the scope of AS-ISK

Species name	AS-ISK		Status	Reference
	BRA	CCA		
Coptodon rendalli	18.0	26.0	Invasive	Tarkan et al. (2017)
C. zilli	19.5	29.5	Invasive	Tarkan et al. (2017)
Carassius auratus	31.0	41.0	Invasive	Tarkan et al. (2017)
Clarias batrachus	45.0	49.0	Invasive	Tarkan et al. (2017)
Gambusia holbrooki	32.0	40.0	Invasive	Tarkan et al. (2017)
Lepomis gibbosus	43.0	53.0	Invasive	Tarkan et al. (2017)
Oreochromis aureus	22.0	32.0	Invasive	Tarkan et al. (2017)
O. niloticus	23.0	35.0	Invasive	Tarkan et al. (2017)
Pseudorasbora parva	40.0	52.0	Invasive	Tarkan et al. (2017)
Pterygoplichthys disjunctivus	37.0	49.0	Invasive	Tarkan et al. (2017)
P. pardalis	31.5	43.5	Invasive	This study
Poecilia reticulata	39.0	50.5	Invasive	This study
Xiphophorus hellerii	46.0	56.0	Non-native	This study
X. maculatus	23.5	29.5	Invasive	Yoğurtçuoğlu et al. (2025)

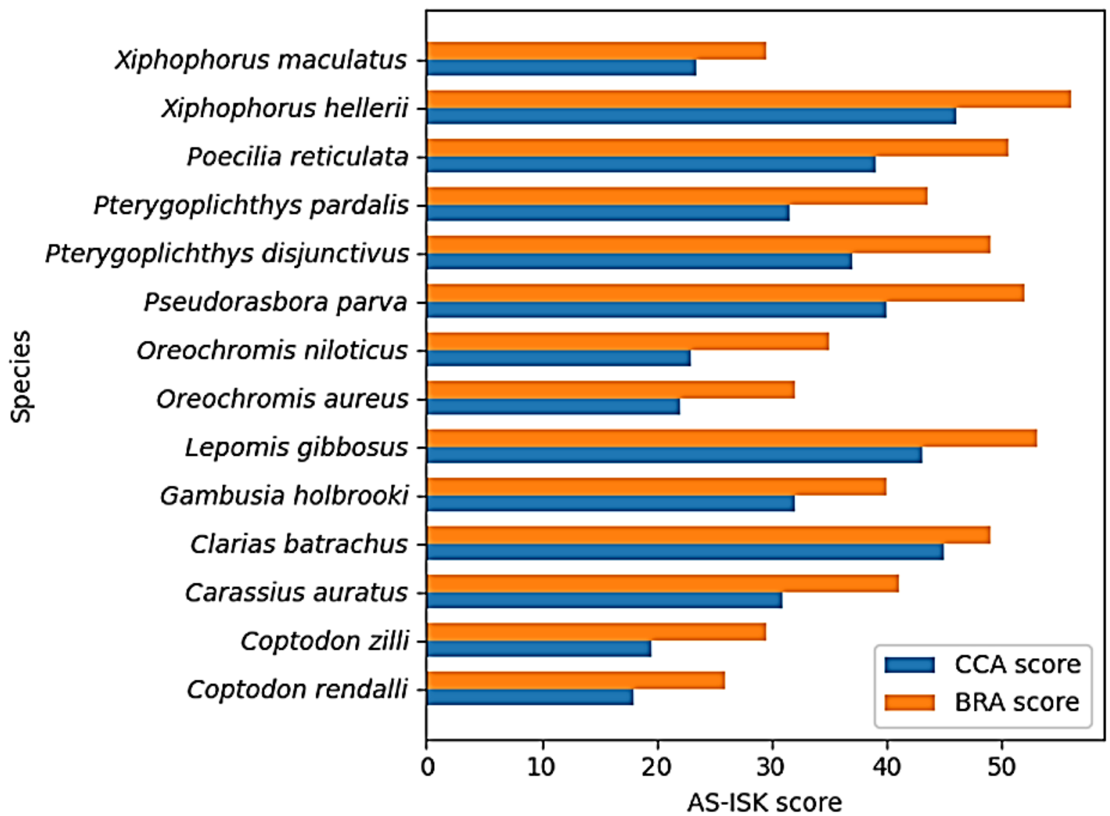

Figure 3. CCA and BRA scores of listed species.

hot springs near Eskişehir (Emiroğlu et al., 2020).

Looking ahead, climate projections indicate that Türkiye's average air temperatures could rise by 0.5-1°C over the next 50 years (Demir et al., 2008; Anonymous, 2015). This warming trend would benefit species that depend on higher temperatures for reproduction and establishing populations. As temperatures rise, species whose optimal living conditions are met may become even more invasive.

The established tilapia species in Türkiye are *Coptodon rendalli, C. zillii, O. aureus,* and *O. niloticus*. These species have mostly been reported in large, successful populations in the Asi, Seyhan, and Ceyhan basins. For instance, *C. rendalli*, *C. zillii, O. niloticus*, and *O. aureus*—originally assessed as moderate risk under BRA—were reclassified as 'highly invasive' when climate change considerations were factored in. A similar increase in risk levels was observed for several other species. These findings highlight how climate change could significantly alter the spread and behavior of invasive species.

The species *C. auratus, Cyprinus carpio, G. holbrooki, L. gibbosus*, and *P. parva* have successfully settled in the inland waters of Türkiye, establishing not only small populations, but also large ones in various lotic and lentic habitats. Thanks to their broad ecological plasticity and numerous advantageous traits, these species have successfully colonized many habitats. They have been added to the list because they are popular as aquarium fish, although they are more commonly used for breeding, in the fish feed industry, for mosquito control, or in aquaculture than in aquarium fisheries in Türkiye.

Apart from these common species, other species with successful populations in a single locality or catchment area include *Pterygoplichthys disjunctivus, P. pardalis* and their hybrids, *P. reticulata, X. hellerii* and *C. batrachus*. *Clarias batrachus* is native to Southeast Asia and is widespread in India, Bangladesh, Thailand, Vietnam, and the Philippines (Froese and Pauly, 2024). The first recorded sighting of the species in the inland waters of Türkiye was in Pınarbaşı Creek (Porsuk River, Sakarya River Basin, Black Sea Drainage) in 2020 (Emiroğlu et al., 2020). Many regions of Türkiye have climates suitable for the biological requirements of *C. batrachus*, particularly temperature and oxygen levels. This increases the potential for the species to become established and reproduce in Türkiye, particularly if it were to escape or be released deliberately (Beatty and Morgan, 2013). In fact, the presence of other aquarium species, such as *P. disjunctivus* and *P. pardalis*, alongside *C. batrachus* in Pınarbaşı Creek increases the pressure from invasive species in the region. The presence of various aquarium fish in the same area suggests they could pose a significant threat to native species over time, potentially disrupting the ecosystem's integrity. *Clarias batrachus* is a tropical species that can tolerate high temperatures and salinity. Its omnivorous diet enables it to play predatory and competitive roles in the food chain. Its diet includes juvenile fish, crustaceans, insect larvae, and detritus (Sharma et al., 2023). This wide dietary range gives the species an advantage in areas where it is invasive, as it can negatively impact local biodiversity by suppressing native species through competition for food (Strecker et al., 2011).

Poecilia reticulata (guppy) is native to northern South America, specifically Venezuela and Trinidad and Tobago. Due to its viviparous nature and high breeding rate, it is one of the preferred species for aquarium enthusiasts and for biological vector control research, specifically for mosquito control. Regardless, by virtue of its high environmental tolerance and adaptability, it can withstand contaminated, oxygen-depleted waters and temperatures. Due to these characteristics, it has the capacity to establish itself and develop invasive populations in tropical and subtropical countries like India, Brazil, and Thailand (Singh and Lakra 2011; Krishnakumar et al., 2009; Magurran, 2005; Deacon et al., 2011). This species was initially reported from natural freshwater of Türkiye in 2019. 12 individuals were reported and analyzed in the aquifer of Çeşme, Ildır (İzmir) (Türkmen, 2020). It is believed that the species was originally introduced and successfully established by local companies that specialize in and trade in breeding aquarium fish for the amateur aquarium market.

The swordtail, *X. hellerii*, is a well-liked freshwater species from the Poeciliidae family. It originated in Central America, specifically Mexico, Honduras, and Guatemala. Sexually mature males can be separated from females based on a distinctive 'sword' shape, a prolongation of the lower caudal fin. This sexual characteristic also gave the species a common name. It has a strong preference for aquaculture use because it has viviparous characteristics and tolerates temperatures of 22-28°C and a variety of other parameters (Froese and Pauly, 2025). This categorizes it as a species with high potential to become invasive. It has been translocated by humans into numerous tropical and subtropical regions, where it has established feral populations, primarily for mosquito control or as an aquarium species. This omnivorous species places pressure on the trophic structure by assuming a predatory and competitive role in the community, preying on plant material and tiny invertebrates (Arthington, 1999). The record of arrival of *X. helleri* into Türkiye was from the Tohma Stream in Darende, Malatya, Tigris-Fırat River Basin in the year 2021. In total, 58 individuals were recorded in this feral population, and a morphological examination was conducted on 10 individuals (Kırankaya and Ekmekçi, 2021).

Pterygoplichthys is a freshwater, bottom-living fish from the family Loricariidae, known as sucker catfish, sailfin catfish, and pleco, originating from South America. They are endemic in the basins of the Amazon and Orinoco. They are involved in eating algae, bottom detritus, and bottom animals. They adhere to the bottom via their body structure, which is provided by hardened body plates and their ventrally located mouths (Çiçek, 2021). Because of their mass sale from the aquarium trade and export for biological control in other countries, this family has found itself among the invaders. *Pterygoplichthys* species multiply extremely quickly, especially in tropical and subtropical oceans. This is because of their tolerance of a very broad range of temperatures (15-35°C) and aquatic parameters, and their ability to obtain oxygen from the atmosphere. They cause serious ecological and economic damage to local ecosystems by forming schools. They degrade water quality by altering the structure of the bottom in bottom-focused regions and endanger biodiversity through competition for nourishment and habitat with local species (Simberloff et al., 2013). The Asi Basin was the site of the first record of *P. disjunctivus* in Türkiye (Yalçın-Özdilek, 2007). In this record, a single specimen was observed in the Asi Basin. Later studies examined *P. disjunctivus*, *P. pardalis*, hybrids, and resident populations in the Pınarbaşı Creek and Porsuk River (Emiroğlu et al., 2016).

Except for the listed species, *Xiphophorus* cf. *maculatus* and *Bujurquina vittata* were reported from the Sakarya River basin for the first time by Aksu et al. (2021). After this, both species, which hadn't been recorded in any research, were found. In the most recent freshwater fish checklist of Türkiye, these species are not listed (Çiçek et al., 2023). These species require more field study and confirmation.

Discussions

The ornamental fish trade is also a source of accidental introductions of non-native fish species into open water systems. A few introductions of exotic fish into open freshwater systems of Türkiye have involved the accidental or deliberate release of aquarium species (Innal, 2012; Mousavi-Sabet et al., 2023b). The aquarium hobby can also lead to detrimental ecological impacts, primarily through the introduction of non-native species into local ecosystems. Research indicates that many aquarium hobbyists inadvertently contribute to the spread of invasive species by releasing unwanted pets into the wild when they outgrow their tanks or become unmanageable (Maceda-Veiga et al., 2014; Rajabi-Maham, 2017). Additionally, the aquarium industry has frequently overfished wild populations to meet hobbyist demand, endangering the sustainability of some species (Gerstner et al., 2006; Raghavan et al., 2018).

Like other environmental changes, this trend is a result of a complex interplay of forces. Maybe the most significant one in the last few years has been the impact of global climate change on our country's freshwater ecosystems. Rising temperatures, reduced dissolved oxygen, altered hydrologic conditions, and increasing nutrient concentrations are transforming the behavior, distribution, and ecological relationships of freshwater fish (Ficke et al., 2007; IPCC, 2021). These transformations have favored non-native fish species—in part those that are immigrating through the aquarium trade—to invade and establish themselves in those ecosystems.

It has been predicted that Türkiye will be severely impacted by the potentially disastrous effects of climate change. In Türkiye, the increase in aquarium fish species observed in recent years is linked not only to growth in trade volume but also to climatic conditions conducive to their survival. A rise in water temperature, especially in the Mediterranean and Aegean seas, facilitates the establishment of tropical species in new sites and the filling of ecological niches. This effect has more serious consequences in freshwater bodies of water far from the sea. In these regions, characterized by sensitivity and vulnerability of their ecosystems, the increase in temperature plays a determining role. An upward shift in the world's temperature, a byproduct of global climate change, has two important outcomes for the successful establishment of aquarium fish in the ecosystems: Firstly, a rise in temperature has been discovered to induce some sort of physiological pressure among indigenous species of fish, and therefore disable their immune systems. It has been demonstrated that rising temperatures are directly associated with decreased oxygen levels in aquatic bodies. This has been shown to decrease the number of species with low ecological tolerance and increase nitrogen and phosphorus loads.

Furthermore, changes in temperature, the most significant parameter for fish reproductive characteristics, pose critical problems during the reproductive period and for egg health, thereby affecting fertilization success and the continuity of the generation. While these conditions may pose significant challenges for endemic species with narrow tolerance limits, they offer a unique opportunity for aquarium fish, which are typically of tropical origin and have broad temperature requirements. Consequently, it is highly probable that these species will fill potential niche gaps. To illustrate, species belonging to the highly endemism-rich genera *Capoeta, Alburnus, Barbus, Squalius, Oxynoemacheilus* and *Seminemacheilus* – all of which are native to Türkiye's inland waters – exhibit signs of metabolic distress when exposed to temperatures that exceed the species' optimum temperature range. Concurrently, these species demonstrate a decline in population size (Top-Karakuş and Tarkan, 2021; Çiçek et al., 2022; Sungur, 2024). Furthermore, rising global temperatures have been shown to enhance the reproductive capacity of non-native tropical species. This has a consequential effect on the acceleration of their life cycles, thus facilitating the spread of said species over a greater geographical area (Duggan et al., 2006). For instance, although *P. reticulata* (guppy) is a tropical species, it is not confined to tropical regions; it can also establish invasive populations in freshwater ecosystems in subtropical and temperate climates, a phenomenon attributable to rising water temperatures. It has been documented that the guppy exhibits an extended reproductive period and increased offspring numbers in response to rising temperatures (Singh and Lakra, 2011; Krishnakumar et al., 2009). Similarly, *P. disjunctivus* has been observed to alter benthic habitat structure by scraping, thereby decreasing oxygen levels and destroying the spawning grounds of native fish species. The species' ability to tolerate wide temperature ranges and to resist low oxygen conditions increases its invasiveness potential in the context of environmental changes triggered by global warming (Nico et al., 2009).

Recent work on species distribution modeling has also revealed that, globally, climate change is expanding the potential distribution space of aquarium fishes. In a Canadian study, Duggan et al. (2006) reported that even at temperate sites, rising average temperatures would increase the likelihood that species such as *P. reticulata* would tolerate the winter months, thereby increasing the chance that such species would establish populations. As a result of one of the modeling studies, there has also been a recorded decline in the numbers of endemic and indigenous species and a continuous shrinkage of their potential regions of spread (Aksu, 2021; Sungur, 2024). Accordingly, global climate change acts as a multiplier, greatly increasing the potential of aquarium fish species to spread as invaders. The combined influence of climate change and non-local aquarium species thus poses a serious threat to freshwater aquatic ecosystems. In highly endemism-rich countries like Türkiye, this issue is even graver and warrants top priority in managing and protecting freshwater aquatic biodiversity.

The introduction of aquarium fish into natural ecosystems poses a new peril: disease and the spread of pathogens. Aquarium fish originated from tropical or subtropical regions and experience numerous transfers as they travel through the trade chain and have the potential to introduce parasites, bacteria, fungi, and viruses not indigenous to natural ecosystems (Daszak et al., 2000; Chang et al., 2009). A particularly illustrative case is that of *Ichthyophthirius multifiliis*, also known as 'white spot disease', which can spread extremely rapidly through the aquarium trade and cause high mortality among fish. This disease, otherwise controllable in closed aquarium systems, is spread to lakes and rivers by aquarium fish released into natural systems and can cause mass mortality, primarily among local fish species. Evidence for the presence of this parasite in Türkiye's freshwater systems has emerged from its association with invaded fish species (Matthews, 2005; Çiçek et al., 2022).

External parasites, such as parasitic copepods, can also be transported by invasive fish. *Lernaea cyprinacea* (anchor worm) originated in Asia and spread worldwide through the ornamental fish trade, causing severe damage to the skin and gills of local fish species (Sharma and Tandon, 1996). Studies of lakes in India have shown that this parasite, introduced with aquarium fish, causes lesions, growth retardation, and increased mortality in endemic fish species (Sandilyan, 2016). Especially in ecosystems such as inland waters of Türkiye, where endemic species are abundant, this risk is much greater (Innal and Avenant-Oldewage, 2012; Koyun et al., 2015; Innal, 2016; Innal and Gianetto, 2017).

Genetic pollution is defined as hybridization between invasive or exotic species and native species, which degrades the genetic integrity of native populations and reduces their long-term adaptive capacity (Rhymer and Simberloff, 1996; Allendorf et al., 2001). This practice also poses a serious threat, especially to endemic species, because they are at greater risk of genetic contamination due to their restricted geographic range and limited genetic diversity. Aquarium trade-introduced species are often hard and highly reproducing species that tolerate a wide ecological spectrum. When aquarium trade-introduced species crossbreed with local species, this may result in local populations losing genetic purity. A very illustrative case is that of *P. reticulata*, for it is well-suited to a range of environments and exhibits high genetic versatility (Singh and Lakra, 2011). In the Turkish case, genetic contamination of aquarium fish has been recognized as a potential, serious threat to inland water systems characterized by high levels of endemism. In Türkiye, few cases of established interbreeding between aquarium fishes and local species have been reported; however, given the very rapid rate at which alien species invade regions, the likelihood of this threat increasing is very high (Çiçek et al., 2022).

The detection of *P. reticulata*, *X. hellerii*, and *X. maculatus* in Sarıkavak Stream, Serik, Antalya, within the scope of the present study, clearly demonstrates that the introduction of aquarium-origin fish into Türkiye's inland waters is a current and ongoing process. Both species are among aquarium fishes with high invasive potential worldwide, owing to their high reproductive capacity, broad environmental tolerance, and strong association with human-mediated dispersal pathways. The presence of these species in a small, ecologically sensitive freshwater system such as the Sarıkavak Stream highlights the potential ecological pressure that aquarium fish exert on the integrity of inland water ecosystems, particularly in a country characterized by high levels of endemism. These records indicate that aquarium fish introductions are not limited to historical or isolated cases but continue to occur under suitable environmental conditions, allowing non-native species to establish in new habitats.

As a result, it is very likely that more aquarium fish could continue to establish themselves in inland waters in the near future—especially as climate change accelerates the process. This trend poses serious risks, particularly to small-sized species that inhabit shallow waters and have limited ecological tolerance. From a management standpoint, species with high basin occupancy likely exert the greatest ongoing pressure on native ecosystems and may require broader, pathway-based strategies—such as better regulation of ornamental fish releases, improved containment in aquaculture, and actions to reduce introduction pressure. In contrast, species with limited distribution present opportunities for early intervention, including containment or even eradication, before they become widespread. Since the data is based solely on presence or absence, it should be interpreted with care—considering sampling intensity, detection likelihood, and timing. Still, basin-level presence remains a valuable indicator for decision-makers, linking species distribution to specific water management regions and helping prioritize surveillance, control efforts, and rapid response within operational conservation and regulatory frameworks.

References

Akhan S., Bektas Y., Berber S., Kalaycı G. (2014) Population structure and genetic analysis of narrow-clawed crayfish (*Astacus leptodactylus*) populations in Türkiye. Genetica, 142: 381-395.

Aksu S. (2021). Current and future potential habitat suitability prediction of an endemic freshwater fish species *Seminemacheilus lendlii* (Hankó, 1925) using maximum entropy modelling (MaxEnt) under climate change scenarios: Implications for conservation. LimnoFish, 7(1): 83-91.

Aksu S., Başkurt S., Emiroğlu Ö., Tarkan A. (2021). Establishment and range expansion of non-native fish species facilitated by hot springs: The case study from the upper Sakarya Basin (NW, Türkiye). Oceanological and Hydrobiological Studies, 50(3): 247-258.

Allendorf F.W., Leary R.F., Spruell P., Wenburg J.K. (2001). The problems with hybrids: Setting conservation guidelines. Trends in Ecology and Evolution, 16(11): 613-622.

Altınköprü, İ. (1983). Süs balıkları. Türkiye İş Bankası Kültür Yayınları. (In Turkish)

Anonymous (2015) Türkiye's fifth national communication to the UNFCCC. Ministry of Environment and Urbanization, Republic of Türkiye. Retrieved from: https://unfccc.int/documents/125025

Arthington A.H., Milton D.A., McKay R.J. (1999). The potential impact of exotic fish species in Australian inland waters. Aquatic Conservation: Marine and Freshwater Ecosystems, 9(5): 435-448.

Axelrod H.R., Schultz L.P. (1955). Handbook of tropical aquarium fishes. TFH Publications.

Baytop T. (1961). Akvaryum balıkları ve nebatları: Bakım, besleme, üretme (2. baskı). Kader Matbaası. (In Turkish)

Beatty S.J., Morgan D.L. (2013). Introduced freshwater fishes in a global context: A review of the Australian experience. In: G.H. Copp, K.J. Gozlan, J.D. Olden (Eds.), Biological invasions in changing ecosystems: Vectors, ecological impacts, management and predictions, De Gruyter. pp: 113-124

Chang A.L., Grossman J.D., Spezio T.S. (2009). Tackling aquatic invasions: Risks and opportunities for the aquarium fish industry. Biological Invasions, 11: 773-785.

Çiçek E. (2021). Recent status of exotic *tilapia* species in Türkiye. Ege Journal of Fisheries and Aquatic Sciences, 38(1): 111-116.

Çiçek E., Emiroğlu Ö., Aksu S., Seçer B., Başkurt S. (2021). Range extension of *Gymnocephalus cernua* Linnaeus, 1758 (Perciformes: Percidae) as a new invasive species for Türkiye. Acta Biologica Turcica, 34(1): 26-30.

Çiçek E., Eagderi S., Sungur S. (2022). A review of the alien fishes of Turkish inland waters. Turkish Journal of Zoology, 46(1): 1-16.

Çiçek E., Sungur S., Fricke R., Seçer B. (2023). Freshwater lampreys and fishes of Türkiye: An annotated checklist 2023. Turkish Journal of Zoology, 47(6): 324-468.

Dalavi S., Pawar B. (2023). Ichthyofaunal diversity and fishery potential of Mandohol Reservoir, Ahmednagar District, Maharashtra, India. International Journal of Zoological Investigations, 9(1): 120-125.

Daszak P., Cunningham A.A., Hyatt A.D. (2000). Emerging infectious diseases of wildlife: Threats to biodiversity and human health. Science, 287(5452): 443-449.

Deacon A.E., Ramnarine I.W., Magurran A.E. (2011). How reproductive ecology contributes to the spread of a globally invasive fish. PLoS ONE, 6(9): e24416.

Demir M., Karaca M., Ünalan T. (2008). Climate change and its potential impacts on Türkiye. In: Proceedings of the International Conference on Environment: Survival and Sustainability, Nicosia, Northern Cyprus. pp: 63-72.

Duggan I.C., Rixon C.A.M., MacIsaac H.J. (2006). Popularity and propagule pressure: Determinants of introduction and establishment of aquarium fish. Biological Invasions, 8(2): 377-382.

Emiroğlu Ö., Atalay M., Ekmekçi F., Aksu S. (2020). One of the world's worst invasive species, *Clarias batrachus* (Actinopterygii: Siluriformes: Clariidae), has arrived and established a population in Türkiye. Acta Ichthyologica et Piscatoria, 50(4).

Ficke A.D., Myrick C.A., Hansen L.J. (2007). Potential impacts of global climate change on freshwater fisheries. Reviews in Fish Biology and Fisheries, 17: 581-613.

Folmer O., Black M., Hoeh W., Lutz R., Vrijenhoek R. (1994) DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. Molecular Marine Biology and Biotechnology, 3: 294-299.

Froese R., Pauly D. (2024). FishBase. https://www.fishbase.se/search.php

Geldiay R. (1985). Süs balıkları yetiştiriciliği. Ankara Üniversitesi Basımevi. (In Turkish)

Gerstner K., Dormann C.F., Seppelt R. (2006). Species richness–environment relationships in European freshwater fish: A meta-analysis. Ecology, 87(5): 1088-1098.

Hall T.A. (1999). BioEdit: a user–friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. Nucleic Acids Symposium Series, 41: 95-98.

Innal D. (2012). Alien fish species in reservoir systems in Türkiye: A review. Management of Biological Invasions, 3: 115-119.

Innal D. (2016). Fish diversity and distribution in the Aksu River estuary (Antalya, Türkiye) in relation to environmental variables. Ecologica Montenegrina, 5: 90-98.

Innal D., Avenant-Oldewage A. (2012). The diversity of fish parasitic Copepoda in Türkiye: A case for the importance of parasite biodiversity. African Zoology, 47(2): 320-326.

Innal D., Gianetto D. (2017). Age structure and length–weight relationship of non-native redbelly tilapia *Coptodon zillii* (Gervais, 1848) (Cichlidae) in the Pınarbaşı Spring Creek (Burdur, Türkiye). Acta Zoologica Bulgarica, 9: 111-116.

Innal D., Sungur S. (2019). First record of non-indigenous fish *Hemichromis letourneuxi* (Cichlidae) from Pınarbaşı Creek (Burdur, Türkiye). Mehmet Akif Ersoy Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 10(1): 90-94.

Innes W.T. (1948). Exotic aquarium fishes. Innes Publishing Company.

Intergovernmental Panel on Climate Change. (2021). Climate change 2021: The physical science basis. Cambridge University Press. ISBN: 978-1009175357.

Kırankaya Ş.G., Ekmekçi F.G. (2021). First record of a feral population of exotic green swordtail (*Xiphophorus hellerii*) with an additional record of guppy (*Poecilia reticulata*) in Turkish freshwaters. Hacettepe Journal of Biology and Chemistry, 49(4): 433-441.

Koyun M., Koca S.B., Öztürk M.O. (2015). First report of *Gyrodactylus salaris* Malmberg, 1957 (Monogenea: Gyrodactylidae) in brown trout (*Salmo trutta fario* L., 1758) from Eastern Black Sea Region of Türkiye. Turkish Journal of Fisheries and Aquatic Sciences, 15(1): 215-219.

Krishnakumar K., Raghavan R., Prasad G., Bijukumar A. (2009). When pets become pests: Exotic aquarium fishes and biological invasions in Kerala, India. Current Science, 97(4): 474-476.

Leal M., Vaz M., Puga J., Rocha R. (2015). Marine ornamental fish imports in the European Union: An economic perspective. Fish and Fisheries, 17(2): 459-468.

Maceda-Veiga A., Escribano-Alacid J., Martínez-Silvestre A., Verdaguer I., Mac Nally R. (2014). What's next? The release of exotic pets continues virtually unabated 7 years after enforcement of new legislation for managing invasive species. Biological Invasions, 16(7): 1345-1357.

Magurran A.E. (2005). Evolutionary ecology: The Trinidadian guppy. Oxford University Press.

Matthews R.A. (2005). *Ichthyophthirius multifiliis* Fouquet and ichthyophthiriasis in teleost fish. Advances in Parasitology, 59: 159-241.

Ministry of Environment and Urbanization, Republic of Türkiye. (2015). Türkiye's fifth national communication to the UNFCCC. https://unfccc.int/documents/125025

Mousavi-Sabet H., Eagderi S. (2016). First record of the convict cichlid, *Amatitlania nigrofasciata* (Günther, 1867)(Teleostei: Cichlidae) from the Namak Lake basin, Iran. Iranian Journal of Ichthyology, 3(1): 25-30.

Mousavi-Sabet H., Vasil'eva E.D., Eagderi S., Vasil'ev V.P., Vatandoust S., Abbasi K. (2023a). Exotic fishes in the southern Caspian Sea basin; with four new records. Iranian Journal of Ichthyology, 10(1): 28-40

Mousavi-Sabet H., Habibi A., Eagderi S. (2023). The first record of Koi fish, *Cyprinus rubrofuscus*, from a natural waterbody in the Hormuz basin, southern Iran. International Journal of Aquatic Biology, 11(6): 605-608

Murchie K., Knapp C., McIntyre P. (2018). Advancing freshwater biodiversity conservation by collaborating with public aquaria. Fisheries, 43(4): 172-178.

Nico L.G., Martin R.T., Schofield P.J. (2009). Non-native suckermouth armored catfishes in Florida: Description of introduction pathways, biology, ecological impacts, and management options. Reviews in Fisheries Science, 17(2): 199-214.

Peel M.C., Finlayson B.L., McMahon T.A. (2007). Updated world map of the Köppen–Geiger climate classification. Hydrology and Earth System Sciences Discussions, 11(5): 1633-1644.

Radkhah A.R., Eagderi S., Mousavi-Sabet H. (2016). First record of the exotic species *Hemiculter leucisculus* (Pisces: Cyprinidae) in southern Iran. Limnetica, 35(1): 175-178.

Radkhah A.R., Eagderi S., Cicek E. (2022). Effects of Climate Change on the Distribution of the Invasive Stone Moroko *Pseudorasbora parva* (Temminck & Schlegel, 1846)(Actinopterygii: Cyprinidae) in Asian Aquatic Ecosystems. Acta Zoologica Bulgarica, 74(2): 317-323

Raghavan R., Ali A., Philip S., Dahanukar N. (2018). Effect of unmanaged harvests for the aquarium trade on the population status and dynamics of redline torpedo barb: A threatened aquatic flagship. Aquatic Conservation: Marine and Freshwater Ecosystems, 28(3): 567-574.

Rajabi-Maham H. (2017). Genetic diversity and population structure of freshwater fishes: A conservation perspective. In: S.N. Meyers (Ed.), Advances in freshwater ecology. Nova Science Publishers.

Reid G., MacBeath T., Csatádi K. (2013). Global challenges in freshwater-fish conservation related to public aquariums and the aquarium industry. International Zoo Yearbook, 47(1): 6-45.

Rhymer J.M., Simberloff D. (1996). Extinction by hybridization and introgression. Annual Review of Ecology and Systematics, 27: 83-109.

Rhyne A., Tlusty M., Kaufman L. (2012). Long-term trends of coral imports into the United States indicate future opportunities for ecosystem and societal benefits. Conservation Letters, 5(6): 478-485.

Rhyne A., Tlusty M., Szczebak J., Holmberg R. (2017). Expanding our understanding of the trade in marine aquarium animals. PeerJ, 5: e2949.

Rixon C.A.M., Duggan I.C., Bergeron M.N., Ricciardi A., MacIsaac H.J. (2005). Invasion risks posed by the aquarium trade and live fish markets on the Laurentian Great Lakes. Biodiversity and Conservation, 14(6): 1365-1381.

Sandilyan S. (2016). Occurrence of ornamental fishes: A looming danger for inland fish diversity of India. Current Science, 110(10): 1870-1874.

Sharma B., Kumari P., Jaiswal M.K. (2023). Food and feeding habits of walking catfish, *Clarias batrachus* and other commercial fish: A review. TIJER-International Research Journal, 10(9): 879-889.

Sharma B.K., Tandon K.K. (1996). Incidence of *Lernaea cyprinacea* L. infection in fishes of a pond in Bihar, India. Journal of Parasitic Diseases, 20(2): 195-198.

Simberloff D., Martin J.L., Genovesi P., Maris V., Wardle D.A., Aronson J., Courchamp F. (2013). Impacts of biological invasions: What's what and the way forward. Trends in Ecology and Evolution, 28(1): 58-66.

Singh A.K., Lakra W.S. (2011). Risk and benefit assessment of alien fish species of the aquaculture and aquarium trade into India. Reviews in Aquaculture, 3(1): 3-18.

Strecker A.L., Campbell P.M., Olden J.D. (2011). The aquarium trade as an invasion pathway in the Pacific Northwest. Fisheries, 36(2): 74-85.

Sungur S. (2024). Species distribution models of Türkiye's endemic genus *Seminemacheilus* Banarescu & Nalbant, 1995 (Cypriniformes: Nemacheilidae). Oceanological and Hydrobiological Studies, 53(2): 177-185.

Tamura K., Stecher G., Kumar S. (2021). MEGA11: Molecular Evolutionary Genetics Analysis version 11. Molecular Biology and Evolution 38: 3022-3027.

Tarkan A.S., Vilizzi L., Top N., Ekmekçi F.G., Stebbing P.D., Copp G.H. (2017). Identification of potentially invasive freshwater fishes, including translocated species, in Turkey using the Aquatic Species Invasiveness Screening Kit (AS-ISK). International Review of Hydrobiology, 102: 47-56.

Top-Karakuş N., Tarkan A.S. (2021). Does non-native pumpkinseed *Lepomis gibbosus* affect endemic algae-scraping *Capoeta aydinensis* in case of introduction to a small stream? An ex-situ growth experiment. Ecology of Freshwater Fish, 00: 1-6.

Türkmen G. (1995). Türkiye'ye ithal edilen akvaryum balıkları ve sonuçları üzerine araştırmalar [Yüksek lisans tezi, Ege Üniversitesi Fen Bilimleri Enstitüsü]. (in Turkish)

Türkmen G. (2019). First record of the guppy (*Poecilia reticulata* Peters, 1859) in inland waters of Türkiye. Journal of Fisheries and Aquatic Sciences, 36(4): 397-400.

Wedemeyer G.A. (1996). Fish health management in aquaculture (1st ed.). CRC Press. 278 p.

Welcomme R.L. (1988). International introductions of inland aquatic species (FAO Fisheries Technical Paper No. 294). Food and Agriculture Organization of the United Nations.

Yalçın Özdilek Ş. (2007). Possible threat for Middle East inland waters: An exotic and invasive species, *Pterygoplichthys disjunctivus* (Weber, 1991) in Asi River, Türkiye (Pisces: Loricariidae). Journal of Fisheries and Aquatic Sciences, 24(3-4): 303-306.

Yoğurtçuoğlu B., Ekmekçi F. (2018). First record of the giant pangasius, *Pangasius sanitwongsei* (Actinopterygii: Siluriformes: Pangasiidae), from central Anatolia, Türkiye. Acta Ichthyologica et Piscatoria, 48(3).

Yoğurtçuoğlu B., Tarkan A.S., Ekmekçi F.G., Kırankaya Ş.G., Kurtul I., Özcan D., Vilizzi L. (2025). Turkish freshwaters as a case of rising invasion risk of aquarium fishes under climate change. Scientific Reports, 15(1): 37657.